Creative structures or structured creativity

– Examining algorithmic composition as a learning tool

Peter Falthin

ABSTRACT
***Creative structures or structured creativity – examining algorithmic
composition as a learning tool***
*How do student composers develop and structure creative resources aided by
algorithmic methods? This empirical study draws from cultural-historical theory
and cognitive psychology, concerning internalization and the concept-development
process in the context of learning music composition: It focuses on cognitive
processes of student composers working to integrate the outcome of composition
algorithms with their subjective compositional aim and modus operandi. However,
in most cases the composer is also the designer of the algorithm or its application to
the compositional problem. Therefore, strategies involved in designing and applying
compositional algorithms need to be considered insofar as they, too, are part of the
integration process.*
*The present study is not meant to be conclusive, but rather to form a point of departure
for further theoretical and empirical study in the field. Results suggest that musical
learning could be interpreted to follow procedures similar to those of Vygotskij's
(1987, 1999) theories of the concept development process. Stages and processes
concerning language-based learning as described by Vygotskij may apply to musical
concept development as well. This has implications for understanding composition
learning, for teaching composition and for designing interactive musical tools.*
*Keywords: Algorithmic composition; Concept development; Composition studies;
Music and meaning; Musical syntax*

Introduction

This article examines aspects of learning music composition, along the axes of concept
development and meaning making. Two students at a music program in upper secondary
school in Sweden are introduced to algorithmic methods for composition. Algorithmic
composition, meaning the application of formal rules to generate musical material and
ideas, is the vehicle to trigger learning and concept development processes in the compo-

sition projects in the study. Computerized algorithms are set up to produce raw material that is edited and assigned musical meaning by the students.

There are at least two aspects of algorithmic composition of special import to the concept development process (cdp). First, mastering the algorithms requires the students to work with aggregate musical data on a fairly high level of abstraction. Second, the musical material that the algorithms produce is meant to challenge the students' imagination. It will be a focal point to se how the boundaries of the students' creative thinking are affected as they process and edit it. The interest is directed towards conceptualization processes as tokens of learning and creativity development, but with a regard for tools and methods as integrated parts of those processes.

This is a qualitative empirical study employing observations and interviews for data collection. The study took place within a course in composition in a music program in upper secondary school in Sweden, from February to April 2010. It consists of observation of five hours of compositional activities and observation of the compositional algorithms and composition fragments produced within the project. Sessions were done on a weekly basis with some interruptions for holidays and other projects. The students were supposed to work in between sessions. After the composition project was completed, interviews were held and lasted for about 30 minutes each. Two 18-year-old students of different gender participated in the study. They had both had training in several music subjects including music theory and computer music. One is a singer and the other an electric guitarist. They are accomplished improvisers and have had previous compositional experiences in different genres.

Purpose and background to the study

The purpose of the present study is to trace the meaning-making and concept development processes in learning music composition, by means of qualitative empirical methods. It includes both explorative and in-depth ambitions in that it will seek to examine the material manifestations of concept development in the compositions as well as in the composition process, and to understand the course of the musical concept development process. This interest for musical concepts concerns both the learning aspects and the artistic expressive aspects.

On improvisation and composition

To organize musical material on an aggregate level is a core competence in both improvisation and composition, but the application of this organization is generally different.

Researchers' definitions of the dichotomy of improvisation and composition commonly include a difference in time-relations between the creative activity and the

produced artifact and that composition can be an iterative process wherein materials and form could be repeatedly edited, whereas the improviser must settle for whatever springs to mind (Sloboda 1985, Wiggins 2007).

An adequate concern in this context is what impact these differences in conditions have on learning and concept development. One interpretation of the problem is that in improvisation, the revision must be applied beforehand, in the preparatory or learning phase, whereas in composition it is part of the making of the actual artifact. A possible implication of this is that learning improvisation would be more dependent on patterning and hierarchical conceptualizations than learning composition that could proceed in a more tentative fashion.

In a way, the present study could be understood to exercise aspects of improvisation, in that the setting of the parameters to steer the algorithms means engaging in preparations similar to those of planning an improvisation. The particular form of algorithmic composition applied in this study, could be said to occupy an in-between position in that it is direct like improvisation, but does not demand aural control of relations between idea and realization to the same extent. In that sense it more resembles the act of composition where materials can be tested, evaluated and transformed tentatively. A similar standpoint, that the use of computer technology in creative music making can blur the boundaries between composition and improvisation, is maintained by Folkestad (1996).

Computer based composition

Studies of learning in computer assisted composition have been carried out for different ages and stages of education starting from children in primary school (i.e. Brown et al. 2010, Dillon 2007, 2009, Hickey 2001, Nilsson 2002, Nilsson & Folkestad 2005, Stauffer 2001) over adolescents in secondary and upper secondary school (Davidson 1990, Folkestad 1996, Folkestad et al. 1998, Savage & Challis 2001, 2002), college students (Ferm Thorgersen 2008, Lupton & Bruce 2010) and professional composers (Dahlstedt 2001, 2012, Dyndahl 1995). The corpus of study includes both formal and informal settings. Taken as a whole, this does not represent a continuum but the extremes of this research corpus constitute completely different activities and the conditions concerning the concept development process are probably quite different across the body of research.

Still there can be reason to consider similarities in methodology across the different categories. Research on composition often seems to be interested in any combination of three aspects: the compositional process, the musical artifacts and the composer's experience. In several studies this has led to engaging in observation for the first two and interviews or other forms of verbal report for the latter (e.g. Burnard 1995, Folkestad 1996, Nilsson 2002). This design seems to be fitting to problems concerning the compositional process and its product and was applied also in the present study. When context and socio-cultural situation are of primary concern (Davis 2005, Ferm Thorgersen 2008,

Savage 2004, 2005, Savage & Challis 2002), there is a tendency to be more theory-dependant or theory-oriented and less methodologically omnifarious.

Symbolic representation and metalanguage in music

Staff-based notation is a cultural tool that besides its denotative function to transfer information between composer and interpreter also has connotative properties concerning musical tradition and convention (Hultberg 2000, 2005) that could be regarded both as a resource and a hindrance. In a study where students were to improvise music and then to notate what they had done, Wiggins (2001) found that the students deliberately simplified the musical structure in order to be able to score it. A similar result was reported by Hamilton (1999) in a study where students were given an assignment first to compose and later to improvise from the same outset. In these and other studies (Allsup 2002, Mc Gillen 2004, Upitis 1990) notation is considered a constraint to musical imagination. This is probably a common problem in student composition projects, but in the present study the situation is to some extent reversed. These students are quite proficient in articulating their musical ideas through notation but in this case they have to compose without the support for structuring that notation can provide, and instead acquaint themselves with other forms of musical representation, like pitch-class technique and chronometric time. In a way, these students are faced with a micro-version of a problem that has been a major concern for the electro acoustic music community for half a century; a search for a graphical representation of the music to facilitate abstraction and working off-line (e.g. Cogan 1984, Keane 1986, Ligeti & Wehinger 1970, McAdams & Bregman 1979, Smalley 1986, 1992, Thoresen, Hedman & Thommessen 2007, Windsor 1995, Wishart 1986, 1996).

On algorithmic composition

Algorithmic composition means applying formal methods to generate musical material (Dahlstedt 2004, 2012, Rowe 2001). Some examples of principles commonly used include:

- Mapping strategies, wherein data structures are transferred between different domains (e.g. Dahlstedt 2008, Eldenius 1998)
- Stochastic methods that employ probability calculations to distribute musical events (e.g. Brown & Gilford 2010, Xenakis 1992)
- Generative algorithms that create patterns of data from mathematical functions or expressions, which would often be performed in some kind of modeling scheme (e.g. Dahlstedt 2001, 2004, 2012)
- Combinatorics and set theoretical methods (e.g. Forte 1973, Rowe 2001)
  Often these methods are combined. Early examples of computer based algorithmic

composition date back to the mid-50s and the works by Lejaren Hiller and Leonard Isaacson at the University of Illinois Urbana-Champaigne, most famous being perhaps The Illiac Suite for String Quartet (Lincoln 1972).

Algorithms could be employed for different reasons: to supply raw material, to make extrinsic reference, to achieve coherence in a composition or to expand one's creative repertory. In the present study, focus is on the first and last of these Categories. The students explore some possibilities of setting up algorithms that employ random generators to operate on various musical parameters. These algorithms supply raw material for compositions and the scheme for the project is that this material together with the method as such, will provide meaning-affordances for learning and developing the students' creative repertory.

Concepts in music

Can musical generalizations be perceptual constructs not subjected to cognitive structuring? From the stance of activity theory Stojan Kaladjev (2009) considers two different kinds of generalizations to be fundamental to musical learning: Auditive generalizations stem from sensory perception and are processed unconsciously, whereas conceptual generalizations are cognitive constructs, consciously developed and embodied in language. Empirical support for the notion of pre-cognitive perceptive concepts is taken from studies of children displaying pattern recognition skills when completing melodic and rhythmic patterns. This restrictive view of conceptual thinking as being bound by language will be further discussed in light of the results of the present study.

Structural properties like the establishment of motives and themes, repetition, variation and conceptions of form were found to be pertinent in vocal and instrumental compositions made by children age 5-8 years (Barret 1998, Davies 1992). The children could apply structural features for which they where not able to give verbal report. It appears they managed to abstract musical structure from pieces they had heard or learned, and re-synthesize it to accommodate their own compositions.

The dialectic between tools and conceptualizations is discussed by Dahlstedt (2012) in a spatial model to illustrate creative process. The conceptual space of possibility is dependent on knowledge and preference in the artist, whereas the tools restrict the possible space in accordance to their physical constraints and cultural inheritance. A work of art, it is argued, comes into being as a result of the discrepancy between the two respective spaces of possibility.

The notion of multiple intelligences as introduced by Howard Gardner (1983), suggesting that intelligence is not one unit that could be measured by a single value (i.e. IQ) but consists of multiple parallel and independent structures, is revisited by Furnes (2009). These structures in turn are made up of hierarchically ordered sub-intelligences, some of which could be shared between the top-structures. Pattern recognition is one

example of sub-intelligence equally important to musical, mathematical and language-intelligence.

The object for research in the present study is conceptual thinking in music, as opposed to concepts about music. Process and structure is the main focus and the semantic meaning of the actual concepts is often secondary. Still, conceptual structures in music demand that there be musical concepts. Already concepts in natural language are prismatic and dynamic in character. They are not a category in any simple sense of the word, but more like a principle that includes some level of abstraction and generalization. Transferred to the music domain a concept could be just about anything that holds a potential for development or transformation: a harmonic progression, a rhythmic principle or a compound of several musical parameters but it could also be larger scale phenomena.

Theoretical considerations

The study takes its theoretical point of departure in Vygotskij's understanding of the forming and development of concepts as represented in his theory of cultural history (Vygotskij 1980, 1987, 1995, 1999). In the following I will briefly touch on the aspects of Vygotskij's theories that appear the most relevant to the present study.

On cultural historical theory

According to cultural historical perspective, psychological processes can only be understood in their historical and social context (Vygotskij 1987, 1999). Unless there is social communication, there can be no development of either language or thinking, neither on individual nor collective level. Language as a vehicle for thinking enables us to define and objectify things and processes, and thereby to think in sequential steps and even build hierarchical structures of thinking (Vygotskij 1987, 1999). Thinking is what raises the function of language above the level of simple signaling; that endows it with a capacity for levels of abstraction, generalization, planning and reflection (Vygotskij 1987, 1999). Through thinking, language is given predicative qualities; we can operate with expectation. But also non-textual works of art carry conceptualizations of impressions, intentions or reflections of their makers'. Whether or not those works can convey those conceptions to a listener, a spectator or an interpreter is a matter of frequent debate. In the heat of discussion it is sometimes forgotten that this debate applies also to text-based communication.

Vygotskij mentions briefly, almost in passing, that creativity and concept development rely on the same processes of dissociation, transformation, association and re-synthesis (Vygotskij 1995: 32). This is the basis for the concept of creativity that is exercised here, and in this context it is the process that merits attention.

Concept development process

Conceptualization, to understand something from a generalized point of view, is paramount to the learning process studied here. It involves a certain amount of generalization even when the object is a specific item; it could have different states or could be seen from different angles or in different light but still be understood as the same object (Vygotskij 1987, 1999). Vygotskij (1987, 1999) subdivides the process of conceptualization into three phases: In the first syncretic phase, objects are classified and ordered due to subjective casual impressions. Extraneous details become part of the perception of the object. The word is merely a part of the structure of the object. The second phase is the complexive thinking, wherein there are actual and objective relationships between one object and the next, but the connections are associative and peripheral in a way to resemble a chain; there is no all-embracing principle involved. The complex is held together by a series of disparate and arbitrary connections that vary over time, whereas the concept relies on significant aspects common to all objects included. The complexive phase could be further divided into associative complex that builds on casual connections, chain-complex which lacks a structural center and builds upon peripheral connections, diffuse complex in which connections are made from similar properties and lastly the pseudo-concept which resembles the true concept but its construction and creation is complexive rather than conceptual. Finally we arrive at the phase of true conceptualization only to find that it too is subjected to subdivision into spontaneous concepts and scientific concepts. The former are products of unreflective generalizations made from experience of participating in society and culture. The latter – scientific concepts – are not to be understood in the scholastic meaning, but regard concepts derived from intentional learning, primarily in school and other formal settings. This is the kind most relevant to this study set in an education context.

Each concept forms a point of orientation for the mind and a collection of nodes for transfer to other concepts. A concept attains its meaning and value from the relationship to other concepts with the same level of abstraction. Its position in the system of concepts is also its level of generalization. Vygotskij (1987, 1999) pictures this in the form of a grid. Equivalence of concepts is when different concepts result in unison meaning. As the generalization level and the equivalence develop, the concept eventually becomes independent of the word, and the ability to remember a thought without words increases. This notion might be of central interest when adapting the structure of conceptualization process to the music domain.

Imagination, in Vygotskian thinking, is a combinatory skill wherein elements from reality are combined in new ways. Experience and emotion are interpreted by means of imagination. Through cognitive process emotion is conjunct to significance and meaning, which concludes that thought and emotion are inseparable. Imagination forms a circle: Perceived parts of reality are transformed through imagination before they reenter reality, all according to Vygotskij (1995, 1987, 1999). The study at hand focuses

on this circular movement in a music composition context; how imagination works to create meaning through new combinations of elements of reality, to build structures and concepts.

Methodological considerations

The main body of data was collected using observations of the compositional activities and the emerging compositions. There was no filming or recording of the workshop observations, only notes taken by the researcher. As for the observations of the artifacts, the students were asked to save copies frequently and every time they made a substantial addition or change. Thus, both the observations of the working process and those of the compositions are longitudinal data. This was a prerequisite to enable the study of the concept development process.

Interviews were held after the composition project was finished and were mainly explorative, guided by a list of topics to cover with the option to elaborate on chosen subjects and to deviate from the list when necessary. The interviews were intended as a method for triangulation of observational data, but also supplied some aspects that were not covered in the observations. The list of topics included: understanding of the task, individual work process, what algorithms were used, what edits were made, experiences of situations, experiences of the process, musical goals and ideas, assessment of learning, assessment of how the newly learnt stuff connected or were related to earlier knowledge. The interviews addressed questions of experience of the process as a whole and in parts, but also recollections of emotional states and reactions. Questions concerning the internalization process and construction of meaning were addressed in an indirect way.

Focus for the analyses are on the Observations, interviews supply additional data and the students' perspective. The student also gave verbal report during sessions but only after the project was finished did we do proper interviews. The choice not to use a camera was due to an ambition to keep the teaching situation ecological and a belief that the researcher's decisions of what to note would be more adequate if taken during the live event than from a video film.

Learning from algorithms

It is a fundamental problem of creativity development to progress beyond what you already know, to extend your sphere of ideas in order to produce novel music. One approach to this problem is to engage generative and algorithmic processes (Dahlstedt 2001, 2004). The idea is to use familiar circumstance to create an algorithm that projects into an unknown space of music possibility. Generally some kind of constraint is neces-

sary in order for the resulting data to have an identity, a potential for meaningful structures. This could either be a part of the generative logic, or employed as a filter after the fact (Dahlstedt 2001, 2004).

As a part of the task of this project, algorithmic methods were employed to provide a learning situation that was both new and rewarding to the students. Rewarding in the sense that they would produce musical material already from the beginning, before the students even could understand how the stream of music events was shaped. The students' first task was to learn the logic of the generative algorithms enough to steer and modify them to produce musical material useful to their purposes. Then they were to make music out of that material by means of traditional composition methods. There were two overarching aspects to the learning process: to learn to setup and steer the algorithms and to expand the creative repertory by internalizing and transforming the algorithmically generated material.

The algorithms designed for this project could not be more complicated than that the students could learn to handle them within a few hours. Still they feature a variety of techniques to randomize or otherwise manipulate parameters of tempo, rhythm, pitch-class, register, articulation, number of voices, dynamics, density (rhythmic intensity) and more. The pedagogical idea is that learning will be engaged in aspects and levels of the compositional process that these students not normally consider.

Design of the task

The participants were introduced to working with generative algorithms making raw material for musical composition. In a series of seminars they learned the basics of using a programming environment (Max/MSP) especially designed for working with music and sound. In the process they were given a set of music algorithms designed by the researcher to generate series of pitches, rhythms, chords, dynamics and combinations of these, using different kinds of randomized processes. The study was deliberately designed so that the students encountered tools of which they had no previous experience, and foreign musical structures they could only learn to control bit by bit.

The setting was just like a normal class in a composition course of this music program only, the number of students was smaller: The students had a computer each and headphones for monitoring. The researcher/lecturer had a sound system and a projector to demonstrate and explain the algorithms and exercises. Tuition was supplied throughout the project, and the students also assisted each other in both musical and technical problem solving. In the first learning stage, the students would just play around with the algorithms. In order to understand the nature of the effect and the possible scope of the outcome, they were to change the variables and data ranges initiating or restricting the randomized structures. Then they were to manually reconstruct the given algorithms to understand the inner mechanics of them. Lastly they were encouraged to modify the algorithms and to connect different patches to form new generative processes. Then
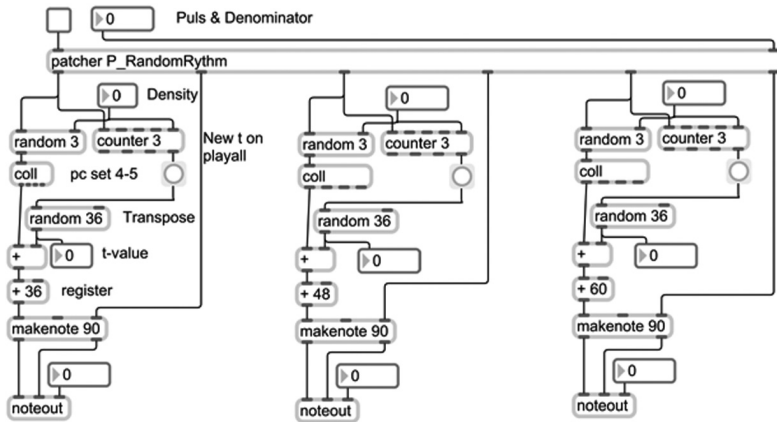
Figure 1: Example of an algorithm in the graphical programming environment MaxMSP, produces three voices of melody based on pitchclass set 4-5 and rhythmic denomination of pulse value.

in the second phase of the project, they worked in a sequencer-environment they were accustomed to and skilled in, doing traditional destructive editing in an audio-sequencer, shaping the raw structures into meaningful musical forms.

Once recorded, the students could play the randomly generated structures over and over, and thereby get accustomed to their sound, whereas in the generative phase it would be different every time. In the second phase they were encouraged to combine the algorithmically generated materials with compositional ideas of their own making, which would help furthering the concept development process (see 3.4, about nodes for transfer between concepts).

Results

The research project concerned the appropriation process; how the students worked to accustom their hearing and understanding to the algorithmically generated material, what they chose to change, transform, add and omit. Two distinctive but interdependent aspects of the process made up the object of study: the learning process and the emerging conceptualizations, and the externalization embodied in musical meaning making in a syntactical sense of the word.

The presentation of the results is descriptive and follows the longitudinal progress of the project, save for the initial subsection. This design is exercised in order to capture the concept-development process. Some reflections are introduced to supply leads for

the following discussion section. Observation for the most part concentrated on composition activities rather than on interpersonal communication and physical activity.

The preceding section described the progression of the study to some extent. Nevertheless I have found it necessary to recall some instances of these descriptions and even to sometimes go further into detail, to guide the reader as to when and in relation to what the results occur. To help distinguish procedure descriptions from actual results, the former are indented and set in a smaller typeface. The stages mentioned in these descriptions concern the distribution of knowledge about the tools: how to handle the composition algorithms. Quotations from the participants are set in italics. The section is subdivided into three subsections: first a summary of the most important results, then follows a run-through of the project with account for the concept development process, and last auxiliary reflections not accounted for in the previous section.

Most important results – a summary

Parallel to processes of disassembling and reassembling the algorithms, reduction of musical information played an important role in the conceptualization process. The students worked to reduce the complexity of the algorithms and of their musical outcome, to a minimum. This was not intended as a part of the design, but a strategy the students applied spontaneously and one that caused them a fair amount of work.

Meaning was assigned to the randomly generated structures by means of (quite strict) formal ordering, thematic processing at phrase level with emphasis on transposition, repetition and rhythmical disposition and last but not least, instrumentation and sound design.

In the second stage, the compositional process did not begin with a seed nor with large-scale considerations, but midways with structures corresponding to a section of one to two minutes of length, that then developed in several dimensions: Their inner structures were refined and articulated, and the application of formal logics expanded them both in length and dramaturgic energy and ambition.

The concept development process

This section follows the project chronologically except for the quotations from the interviews (set in italics). Interviews were held after the fact but certain statements were allocated to the phase of the process to which they apply. The chronological layout is there in order to be descriptive of the concept development process.

Syncretic phase

In the students' first encounter with the programming environment they experienced chaos and disorder. The user interface did not resemble anything they were used to and it was hard at first to understand the nature of the different items. Furthermore, the first

very simple algorithms the students were presented with produced some quite harsh music structures.

> Stage 1. Pitch: In the very first exercise, we used a metronome object to trigger a random generator connected to objects that turned the numbers into sounding notes. Possible manipulations were the speed of the metronome, the range of the random object (note-range), durations and register. After some exploring of the possibilities to adjust the input data ranges, the students were asked to reconstruct the algorithm. Then we did some variations and additions to the structure and continued to adjust the data ranges for these enhanced algorithms.

At this stage conceptual learning concerned understanding the fundamental idea of applying algorithmic methods including handling the particular tool (the programming environment) and its' implications for composition and music making. Some of the key-concepts included being able to parse musical parameters and to understand and apply them on an aggregate level, and to understand the symbolic representation of these parameters in the user interface. As an example of the latter, pitch is represented by midi note-numbers (which then is scalable at the sound source) meaning scales, chords and series are constructed by either filtering or applying a routine of converting absolute note-numbers to pitch class representation, and then back again.

At first the students just turned the algorithms on and off and changed the data-ranges for the random generators. There was so much information to process about the user interface design of the programming environment that the students needed step by step guiding for these first exercises. They had to concentrate on one item at a time and were unable to perform a sequence of steps like piecing together an algorithm following a role model. This is not to be considered a shortcoming but a natural first step in learning a complex tool.

Rather quickly the students learned the basics needed to handle these simple algorithms: to understand the difference between objects and messages and basic principles for connecting these, to set the boundaries for random generators and to locate and manipulate basic music structure data. Still there was no evidence of the students' ability to ideate any musical ideas let alone create new patches of their own in this environment. They were just modifying the given patches by reconnecting the objects in them and manipulating input data ranges. This learning situation fits the description of the syncretic phase (Vygotskij 1987, 1999) where knowledge is fragmentary and casual.

By the time of the interview, after having learned to manage these and other much more sophisticated algorithms, and having completed the composition project the recollection of the event is more moderate. The shift in perspective and sentiment is in itself a token of learning.

W: At first it seemed hard to get a grip of the tools and methods; difficult to get it to accord with to my own ideas.

Furthermore it is not altogether an accurate account of the situation. It was not until later in the process that she tried and failed to realize her original musical ideas by means of the algorithms. Merging these two stages in the cdp into one notion is an act of generalization.

Entering the complexive phase; from associative to chain complex
One of the students asked for algorithms that allowed for changes or variations of the rhythmic content, which I consider the first explicit sign of connecting this learning situation to compositional thinking; a first step towards internalization.

Stage 2. Rhythm: We kept all the variables from the first stage, but focused on rhythmical structures. This was accomplished by using a denominator to the metronome, set to subdivide each beat by an adjustable range of values, but restricted to switch subdivision only by the pulses. To introduce the option of rest, a density parameter was included.

The procedure was similar to that of the first stage: The students learned to understand the algorithms by first altering data ranges, then mimicking the algorithms and finally modifying them. A conceptual problem in stage two concerned that the metronome pace is set in milliseconds meaning a higher value results in a slower tempo, which also has some consequences for the subdivision of beats. In the program, rhythmic representation is additive. In order to allow for divisive rhythmic patterns we set up a hierarchy of several metronome objects guided by denominators and counters in order to keep complex tuplet-rhythms within the beat.

M: I learned to understand the provided algorithms enough to change their settings and to modify them, not to have an entirely different result but to understand the principles of their functions.

At this stage the students began to manage the algorithms enough to steer the outcome in a way to resemble manually composed music, which need not be a goal but again, was a token of the internalization process. By trying to control the randomized parameters in a direction to make it possible to aurally grasp their musical outcome, the students indicated that they were beginning to subject their work to musical ambition. Credible musical structures helped to trigger the compositional imagination, which made them useful for further elaboration.

Stage 3. Sound: We made a deviation from the composition project and spent some time on constructing a software synthesizer in the programming environment. The synthesizer never found its way into the composition project so in this context it would be regarded an exercise to learn more about programming and to widen the notion of the affordance of algorithmic composition. When we went back to the composition project, we patched the MIDI stream of the algorithms to another program for more sophisticated sound-generation. Algorithms from stage 2 were varied and expanded on, and there were some new ones added that introduced new objects and new ways of structuring.

Two features were instrumental in furthering the concept development process: The students began to use more differentiated types of sound to replace the sampled piano sound through which the musical structures were initially realized, and they lowered the musical tempo considerably. More natural sounding instruments together with slower tempi afforded a skew of perspective that facilitated musical meaning making and made the whole situation less abstract, as was both observed by the researcher and verbally reported by the students (during session). This made it easier for the students to assess how ordering and tuning the algorithms affected the structural complexity. Conceptual learning in this stage concerned connecting the newly learned techniques and conceptualizations to internalized musical knowledge and beginning to appreciate their affordances for musical meaning making.

Among tokens observed were that the students began working more independently and their efforts to arrange the parameter-space became more goal-oriented, layered and nuanced. They iteratively adjusted the parameters in search for specific results.

From observing the working situation, it seemed the mode of thinking was now rhapsodic and associative where casual and fragmentary before. The work process was more stable and continuous than before and the students were more prone to experiment with settings. There is no objective measure of these nuances, but that there had been a development from the first phase was quite clear, and the students were now in the process of forming an internal image of the working process and musical purpose. Individual variation was considerable, but more so in terms of musical aim, preference and ambition than concerning the learning process.

Description of two individual projects; From diffuse complex to pseudo-concepts

Stage 4. In the last phase of the project, the students were to record the randomized structures into a sequencer program for manual editing. They were familiar with the sequencer program and had used it in several projects of different kinds before. The observations now concern the artifacts, the actual compositions, rather than the working situation.
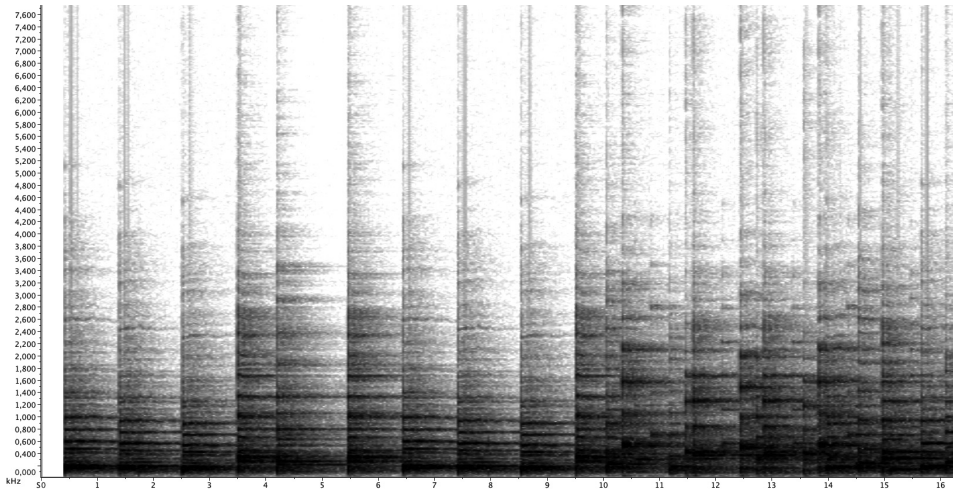
Figure 2. Spectrogram of excerpt from W's composition

Here, conceptual learning and musical meaning making are intertwined. The algorith-mically generated material represents the new object that is confronted with internalized musical knowledge and preference inside a familiar working environment.

Student W set the algorithm to play one single melody-line at a slow speed. She copied it to three different tracks and chose a pizzicato cello-sound to play it. In the first section the different voices were transposed to form a first inversion triad that was played in rhythmic unison. After this thematic head, the three voices formed a canon, still transposed and with small subtractions and edits made to the parts, presumably to make it more organic and less obvious as a canon. The voices gradually diverged rhyth-mically, rendering the music more vigorous and energetic by and by. She had prepared for a fourth part playing harmonies derived from the contrapuntal voices with a soft and mellow pad-sound, but ran out of time before it was realized. The process was first to restrict the algorithm to produce a quite simplistic and tangible melody, only then to blur that clarity by means of traditional techniques. This bears witness to a struggle to grasp and control the algorithms although the musical imagination calls for more excitement. The melodic line suggests a succession of tonalities and it is clear that the harmonies that result from the transposed voices are influenced by this linear structure.

Student M treated the algorithms in a similar fashion; he cut out the polyphony by reducing the algorithm until it produced a single-line melody, and lowered the tempo. Once the MIDI stream was recorded into the sequencer, he built a sinewave synthesizer-sound with an envelope to make it sound like a backwards recording. The melody was copied into two more tracks but instead of transposing the notes, the synthesizers were detuned to form the interval of a major ninth and a quartertone respectively. All three tracks were recorded into an audio track, which was then reversed to give it a bell-like
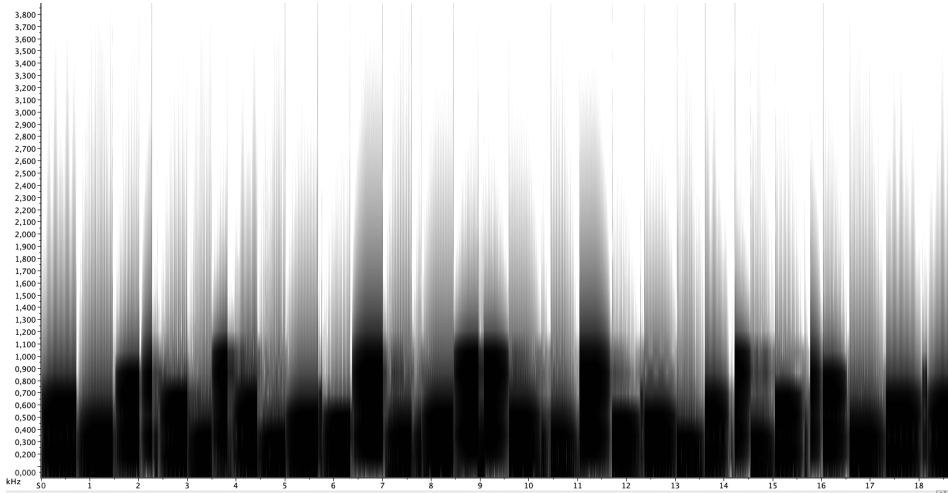
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Figure 3. Spectrogram of excerpt from M's composition

sound; the reversed backward melody now sounded forwards! The whole procedure was repeated and then recorded into a new audio track.

Post festum reflections

The following sections are meant to bring up aspects surfaced in the interviews that are not already accounted for in the previous sections. The section is subdivided into three sections concerning problems of procedure, experience and goals and strategies respectively.

Procedure

The students confirmed that they learned to understand and handle the provided algorithms and to modify them to some extent. Pitch and rhythm were the parameters given most attention in the algorithmic part.

> *W: I used the algorithms mostly for generating melody and rhythm.*

> *M: I didn't create any new algorithms from scratch but I modified some of the given algorithms and changed the settings of the objects and messages.*

Working with the audio-sequencer in the second phase, both students said they had performed editing of the details of the recorded sequence. They applied transpositions to parts of the material, and they both concentrated on melody and rhythm in their editing of midi-data, which is not to say that there was no harmony.

W: I made substantial edits to the randomly generated music. Mostly I cut and pasted and applied transposition to the fragments.

M: In one section where the voices had been moving in parallel, it was to come to a climax. There I gradually transposed the lower voices until they coincided with the upper voice at the climax. Then there was a reiteration of the opening phrase, this time in a lower register.

M said he used a distortion effect on one of the voices to make it come to the fore. He did not add any new (midi-)notes after the randomly generated material was recorded, but concentrated his editing to manipulating how the software instruments played the sequence and on the soundfiles rendered from these manipulations.

M: It attracts me, this way of taking a material through several stages. It is like having different rooms were you subject the material to different processes. That is something I would like to continue doing.

Decisions upon form, disposition and character of the pieces were largely done in the manual editing phase in the sequencer environment. Recursion happened for the most part within the different stages and not so much between them, as it were.

Experience

M: Chance is beautiful and holds great artistic value.

M was attracted by the idea of having uncontrolled streams of notes and rhythms possibly render beautiful music, and compared this notion to free improvisation. W sometimes felt limited by the algorithms.

W: I did not have a preconception of what music would come out of the algorithms, but when I tried to combine the random generators with my own structured ideas it proved difficult.

She found it hard to get the algorithms to comply with her own compositional ideas, which is a feasible complaint considering that much of the work was about setting boundaries for random generators.

W: I didn't have enough time to work on the projects as much as I had hoped to do, but still it gave me a fair idea of what you can do with random generators, what their affordances are.

The students had very differing opinions of the level of difficulty of the task of the project. M thought it was both easy and rewarding, and he was the one to become interested and has continued developing skills for the programming environment and working with random and other strategies for aggregate music generation. W thought it was rather difficult and complex. She said it was interesting to try but she has not continued working in this direction by herself, nor does she experience any urge to do so.

> W: It was interesting to learn to handle the programming, but it is probably nothing I would choose to do on my own. It is always a good thing to widen your musical perspectives, but I think, as a person I am not adventurous enough to really embrace and enjoy this way of working with composition.

The comment indicates that she had not accepted some of the fundamental conditions for engaging algorithmic methods for composition. She experienced a conflict between her subjective musical agenda and the randomly generated structures. For M the project integrated well with his compositional development.

> M: One thing that I have done before but that became clearer to me, that was more clearly inscribed in my head, was my predilection for working with a small set of material and to make it grow from there. And that material could be anything – even randomly generated. Before, I always used to start from a sound or a material that I really liked; something that made me feel that, yeah, I can really develop something from this. Through this work I've come to realize that it could be even easier and more fruitful to work with form and voice leading from a more neutral material.

He also said that working with this project has opened his mind to the notion of chance and random and has made him interested in continuing exploring the field.

> M: Before we did this project I had difficulties working with chance as a parameter. Now, partly because we've investigated so thoroughly the possibilities to make use of random and partly because I read a book about John Cage and his approach to the matter, I sense that random structures can be precisely as beautiful and valuable as something carefully thought out over a long period of time.

Goals and strategies
Although the final compositions were very strict in form, none of the students claimed to have a preconception of the form, but it grew out of working with the material. W had an explicit preconceived idea that she tried to realize by steering the random generators. This was experienced to be difficult (see above). M had an image of having the algorithms produce a massive stream of notes and musical events. He was looking for a certain kind of flow, "fast and beautiful".

> *M: When I think about randomness in music I associate to the free-form improvisers that I listen to a lot, that have good command of their instruments but sometimes use playing techniques that involves chance to the point that there emerges streams of notes that they cannot control. That fascinates me and that was what I was trying to get at: some kind of stride, fast and beautiful.*

This idea was never realized though, but substituted for another that began rather calmly and had the voices entering one by one, moving in parallel until the aforementioned gradual transposition set in. After the climax the form reverted and a new iteration began. This idea of musical form was not preconceived but was born in the process of working with the material.

Discussion
Analytical comment of two student compositions

This section is written in reference to Results: 5.2.3 Description of two individual projects; From Diffuse Complex to Pseudo-Concepts.

Student W's composition
In the algorithmic phase there is an endeavor for simplification that is inverted as soon as the material is fixed, and the familiar tools of manual composition are put into play. The design of the project if anything, suggests the opposite procedure, that the algorithms produce complexity and the manual editing be used for cleaning up, ordering and thereby arriving at musical meaning making. In other words, when working with the algorithms W is occupied with controlling the mechanisms and understanding the relation between the settings and the outcome. There is not much to give evidence of a musical vision. Later when working with the sequencer, the application of tools and techniques is transparent and focus is on musical development. The randomly generated quite rhapsodic melody is given musical meaning by formal structuring based on analysis of its intrinsic qualities, like harmonic content and interval structure. The situation is ambiguous but all in all it seems to correspond to what Vygotskij refers to as pseudo-conceptual (Vygotskij 1987, 1999); the last complexive phase that resembles the structure of true concepts but that is not conceptually constructed.

Student M's composition
This very brief composition almost exhausts the catalogue of semantic tools applicable to musical phrase, presented by Sloboda (1985). There is repetition at three levels, variation inside the melodic fragment, vertical expansion in terms of transposition and the application of micro-intervals, and the retrograde is a form of contradiction. The

sequencer-file also had three more synthesizer tracks with elaborated settings for the instruments, but no music added to them yet. This hints that the work was interrupted by the ending of the project and that there were plans for a larger piece.

The focus on sound design and the way it was carried out, in terms of tools used and the nature of the sounds, suggest impact from another study, in which the participants were to create sounds and sound-based compositions by means of additive synthesis where this student also participated (Falthin 2012). This in itself is a token of the concep- tualization process and an example of what Vygotskij (1987, 1999) refers to as nodes for transfer between concepts. The ability to integrate these two newly gained concepts into one project is a token of conceptualized learning.

In the interview, M stated that he was skeptic at first to let random and chance into his compositional toolbox but during the project he converted to the opposite position.

Through the project, M said his predilection for constructing musical form from a small set of material, was strengthened and also that this material could be just about anything, even randomly generated. The fact that this material did not have a very strong identity or impact, made it easier for him to concentrate on developing the form. From this perspective it is evident that the project had contributed to his concept development processes in music composition on a larger scale.

An interesting detail is the different application of transposition in the two compo- sitions. W worked inside the midi sequence to transpose single events and phrases, and also applied static transpositions to whole sequences. M engaged in transpositional process by continuously changing the tuning of the software instruments playing the sequence. One voice was kept to a fix transposition whereas the others started from an offset transposition and gradually closed in as we approached the climax of each section. This music employed transposition by micro-intervals.

Concept development

The idea of concepts and concept development processes in other areas than language is supported by the theories of multiple intelligences (Furnes 2009, Gardner 1983). A major point of the theory is that such intelligence structures can be developed. Furnes (2009) argues that learning in one area can even further the development of intelligence in another area, to the extent that they share sub-intelligences. In the context of the present study, structural aspects are more intriguing than the resulting effects though: If intelligences pertaining to different abilities are structured in similar hierarchical webs and even sharing resources, it would be plausible to think that also the processes for their development share some properties.

Findings in the study could be interpreted in terms of Vygotskij's theories of concept development in language-based learning (Vygotskij 1987, 1999). In the appropriation process, the algorithmically generated structures underwent analysis and re-synthesis and became generalized to the point that they could be put into a musical context and

their intrinsic properties could be used as affordances for musical elaboration. An aspect of this is that both the algorithmically generated material and the manual compositional strategies applied were radically reduced in complexity before they were united in the process to create musical meaning. This complies with a fundamental notion in cultural-historical psychology, that in the concept development process the old conceptual structures are torn down and new structures are built, not from the elements of the torn-down structures but from a reordering of already structured concepts (Vygotskij 1987, 1999).

As mentioned before, there is a conditional difference between the concept development process as described by Vygotskij (1987, 1999) that refers to small children starting from literally nothing, and that of the adolescents in the study. This is why a design, where the participants had no preconceptions either about the process or the outcome, was chosen. Still, as the students start developing their concepts in algorithmic composition, they already have a fairly developed system of concepts in music and music composition even, which will probably help to speed up the process but will also possibly blur the linearity of the process and create some hybrid-states not described by the theory, when the primitive pre-conceptual stages encounter the accomplished and internalized compositional concepts already at the students' disposal. A token of this can be seen in the frustration of the student trying to get the algorithms to comply with her musical imagination, but also in the application of traditional contrapuntal techniques to the algorithmically generated material. An implication of all this seems to be that the encounter of concepts in different state of development is vital to the creative process. Hence, not every single concept has to be constructed from the syncretic phase and up but rather, some fundamental concepts will make the whole journey while others will branch out or be spin-offs from these. According to the theory, new concepts are built by deconstructing and reconstructing already established ones. The concepts grow both in size and in numbers and the reconstructed concepts integrate the new knowledge to the conceptual system, leaving established knowledge somehow to be affected by this entrance. There are a number of different ways this can happen:

- The concept can be strengthened by affirmation or addition, as when M claims his bias for building large-scale forms from small materials was confirmed and nourished by the project
- The concept can be put into new perspective, enabling new nodes for transfer, like acknowledging new structural levels in composition, as did both students
- The concept can be altered, i.e. it can change its range of meaning affordances or level of abstraction, like the student expressing a new attitude towards chance
- The concept can be inverted, as when M flips his backwards-enveloping sound backwards to make it sound forward.

The conclusion that auditive generalizations are pre-cognitive and do not lead to conscious concept development, as reported by Kaladjev (2009) is contradicted by the

findings of Davies (1992) that young children could abstract structural properties from learned songs and apply them to their own compositions. This must have included parsing and dissociation of those properties before rescaling and adjusting them to fit the new musical context, activities that require cognitive processing and are symptomatic of the concept development process. The children composing in Barret's (1998) study used structural features of which they could not give verbal report. This is suggestive of a non-verbal concept development process in progress.

Pattern recognition abilities, like in the empirical studies presented by Kaladjev, are commonly ascribed to mathematical and spatiotemporal competence, (Fagius 2002, Furnes 2009, Lerdahl & Jackendoff 1983, Sloboda 1985, Wallin 1982) and although to a great extent independent of language, these competences are indeed conceptual to their nature. To restrict conceptual thinking to always involve a meta-level of verbalization in natural language seems to me an underestimation of the meaning potential not only in music but also in disciplines like mathematics and visual art for instance. The structure of musical learning of the participants in the current research project essentially parallels the concept development process in language, as described by Vygotskij (1987, 1999). Concepts in music and language alike result from generalizations of both implicit and explicit learning and they appear to be operationalized in similar ways through the different phases of the process.

The historical meaning of musical improvisation has to do with improving an already established composition and was a core competence expected from musicians in Western concert music culture up until the early Romantic era. For those musicians like for modern day jazz or pop musicians, improvisation commonly meant musical reflection over some premeditated musical entity, typically a composition. This aspect is not taken into account by the researchers in Wiggins (2007) study distinguishing between composition and improvisation nor by Sloboda (1985) who considers the opportunity for revision to be the watershed moment. Folkestad (1996: 40) inverts the logic and suggests that composition is improvisation plus reflection. This seems to imply that improvisation is created from nothing. According to cultural historical theory though, creative fantasy works by combining perceived objects with internalized objects in new ways (Vygotskij 1995). The compositional process in the present project involves improving the raw material streaming from the algorithms and hence, is partly improvisational in the etymological and historical sense of the word. The algorithmically generated materials, as well as the structures themselves, undergo processes of dissociation, transformation, association and re-synthesis in connection with internalized musical concepts in the course of composition. This is supportive of Vygotskij's (1995) notion of the circular movement of imagination and the affinity of processes of creativity to cdp.

The role and import of the interviews

As documentary validation the interviews had a limited value as they were held a while after the project was finished and the students had difficulties remembering what they did and what their thoughts were in the early phases of the project, let alone give account for their compositional processes as a whole. Equally interesting to what the students said they had done is to note all the musical processing they applied but did not recall in the interview situation. When probing for some of these details their reactions indicate that they were not really aware of all these features or they were not thought of as explicit strategies. It was just something they did, more or less in an improvisational manner, which works to support the notion that computer based composition occupies a position in-between composition and improvisation, and that improvisational imagination depends on applying conceptualized knowledge to new situations (Vygotskij 1995).

Instead the role of the interviews as vehicle for externalization of the learning experiences surfaced as a prominent feature. In this capacity they can inform us of certain aspects of the maturing cdp. Issues of experience and emotion are important to the cdp (Vygotskij 1987, 1999) and were brought up in the interviews. Since interviews were held after the fact, emotions were not monitored instantly but were filtered through memory over a time-span of three months. Emotions are casual events, not easily remembered in all their nuances, which leads to the assumption that the emotions expressed in the interviews represent merely a fraction of what took place during the project and that these reported emotions also were subjected to the conceptualization process and thus balanced and emblematic.

But the interviews are not there to give an accurate account of the sessions but to provide an opportunity for externalization and reflection. They are part of the cdp and their after the fact perspective can be regarded a sign of learning.

Implications for further research

The intimate setting with a small group of students working almost as a team, discussing problems and helping each other out, has probably narrowed the span of variation in the results. The study should be repeated in different environments in order to produce a richer repertory of results and more detailed report of relationships between musical syntax applied and the construction of meaning in the concept development process. Composition activities could be measured and quantified, and sequences of activities mapped in order to trace the concept development processes more closely.

The tendency that creative processes seem to benefit from comprising concepts in different stages of development merits further study. The compositions in the study could be compared to earlier compositions by the students and to their instrumental and vocal activities in search for tokens of connections between the creative process and inter-

nalized knowledge. Musical and other life experiences were shown to have an impact on the music of young composers in a study by Stauffer (2002). It would be of great interest to the study of concept development process in music if such connections could be established in relation to composition activities and creative processes.

The results point also to differences in the process of externalization in language and music respectively. Language is linear and sequential whereas music is multidimensional and can even display several parallel multidimensional structures. This needs to be further examined and its implications for a functional analogy between language-based learning and musical learning evaluated.

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Fil. Lic. Peter Falthin
Äppelviksvägen 28
16753 Bromma, Sweden
peter.falthin@kmh.se
Affiliation: Royal College of Music in Stockholm (PhD-student)