Heuristic Models for Decision Making in Rule-based Compositions

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ABSTRACT

Scores that require participants to negotiate inter-personal relationships during performance encourage the development of individual and collective strategies for decision-making as part of the performance practice. Such strategies might be codified through rules specified in the score or developed more informally through the preferences of the performers. In both cases, models drawn from decision-making theory can be usefully applied to help explain the ways in which composers initiate these processes and how performers respond to them. In particular, heuristics suggest possible explanations for the ways in which such pieces operate in practice. A heuristic is a useful decision-making strategy that "ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods" (Gigerenzer & Gaissmaier, 2011, p. 454). By reducing the amount of information to be considered, there is a corresponding reduction in the cognitive effort required to make a decision.

This paper considers the creative potential for heuristics as a compositional strategy. It explores implicit uses of heuristics in work by Christian Wolff and Joseph Kudirka, as well as my own recent music. It examines how performer decisions in such pieces create different modes of interaction between individuals and rules. The practice presented in the paper provides possible models for embodying heuristics, and decision-making theories more generally, as a compositional strategy. I contend that defined heuristics are present in existing compositions where performers are required to make judgments based on available information, and that composers have deployed such heuristics intuitively. By making links between current heuristics theory and compositional practice, as well as showing how such theory might actively inform the creation of new work, the paper suggests future possibilities for creative practice.

I. INTRODUCTION

Scores that require participants to negotiate inter-personal relationships during performance encourage the development of individual and collective strategies for decision-making as part of the performance practice. Such strategies might be codified through rules specified in the score or developed more informally through the preferences of the performers. In both cases, models drawn from decision-making theory can be usefully applied to help explain the ways in which composers initiate these processes and how performers respond to them. In particular, heuristics suggest possible explanations for the ways in which such pieces operate in practice. A heuristic is a useful decision-making strategy that "ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods" (Gigerenzer & Gaissmaier, 2011, p. 454). By reducing the amount of information to be considered, there is a corresponding reduction in the cognitive effort required to make a decision. While some previous research has posited that heuristics produce more errors in comparison with logical and statistical models as a result of the "accuracy-effort trade-off" (Gilovich, Griffin, & Kahneman, 2009; Kahneman, Slovic, & Tversky, 1982), recent studies have shown that heuristics outperform such rational methods in environments to which they are "ecologically rational" (Gigerenzer & Gaissmaier, 2011). In particular, heuristics are suited to environments where some relevant information is unknown, contrasting the use of rational methods in the bounded laboratory conditions of "small worlds" with the need to find ways to address the complexity of "large worlds" (Binmore, 2007).

This paper considers the creative potential for heuristics as a compositional strategy. It explores implicit uses of heuristics in work by Christian Wolff and Joseph Kudirka, as well as my own recent music. It examines how performer decisions in such pieces create different modes of interaction between individuals and rules. The practice presented here provides possible models for embodying heuristics, and decision-making theories more generally, as a compositional strategy. I contend that defined heuristics are present in existing compositions where performers are required to make judgments based on available information, and that composers have deployed such heuristics intuitively. By making links between current heuristics theory and compositional practice, as well as showing how such theory might actively inform the creation of new work, this paper suggests future possibilities for creative practice.

II. HEURISTICS

According to Gerd Gigerenzer, heuristics are composed of three building blocks that have specific functions in decision-making: search rules, stopping rules, and decision rules (Gigerenzer, 2002, p. 43). Gigerenzer splits search rules into two categories: the search for alternatives, and the search for cues. The search for alternatives derives from Herbert Simon's concept of *satisficing* (1956, p. 136) in which the "search process goes on until a satisfactory alternative is found that reaches or surpasses the aspiration levels on the goal variables, and then this alternative is taken" (Selten, 2002, p. 14). In this model, a search continues until an option is presented which will suffice: it may not be the perfect option, but it is satisfactory. The alternatives are not known in advance, but the criteria for their recognition allow them to be found. The search for cues operates within an environment where the alternatives are known in advance, and their recognition terminates the search. Stopping rules are the conditions that terminate each search and "involve simple criteria that are easily ascertained" (Gigerenzer, 2002, p. 44) and decision rules determine what happens when the search is stopped. The different ways in which these building blocks are configured defines individual heuristics.

As an example, in the *take-the-best heuristic* cues are compared in a ranked sequence until such a comparison can discriminate between available options. In a study of which of two residential properties was more likely to be burgled on the basis of eight cues (Garcia-Retamero & Dhami, 2009), professional burglars judged the presence of an alarm system to be the most important factor. If one property had an alarm

and the other did not, then the non-alarmed property would be selected. If both or neither property had an alarm then discrimination using that cue was not possible, so the second ranked cue (location of the property on the corner or in the middle of the street) was used, and so on. The search rule here is cue-based (does one property have an alarm? is one property on the corner?), the stopping rule is activated when the search rule can discriminate between a pair of properties, and the decision rule indicates the action to be undertaken on termination of the search (burgling the property, or not).

Gigerenzer also introduces the notion of *ecological rationality* as a way to assess "the match between a strategy and an environment" (Gigerenzer, 2002, p. 46). He notes that such a match results in "adaptive decisions that combine accuracy with speed and frugality" and that heuristics are more robust "when environments are noisy and information is scarce." In particular, where a heuristic is ecologically rational it produces results that match or exceed those of more computationally-intensive and time-consuming methods (Gigerenzer et al., 2002). Shah and Oppenheimer (2008, p. 209) propose five distinct methods used by heuristics to increase the efficiency of decision-making in this way:

1. Examining fewer cues.
2. Reducing the difficulty associated with retrieving and storing cue values.
3. Simplifying the weighting principles for cues.
4. Integrating less information.
5. Examining fewer alternatives.

In summary, heuristics reduce the amount of information, or simplify the structuring of that information, that is minimally necessary to make decisions in order to "employ a minimum of time, knowledge and computation to make adaptive choices in real environments" (Gigerenzer & Todd, 2001, p. 14).

III. RULE-BASED COMPOSITIONS

One such real environment is found in compositions that require performers to make decisions based on cues in live performance. Typically such pieces use verbally-expressed rules which tend to be internalized by the performers during rehearsal and preparation, and then activated in the performance, often from memory. The rules might govern the way performers respond to the events that unfold during the performance, controlling anything from individual moments through to entire pieces. Given the possible complexity of musical performance as an environment, heuristics are useful because they enable performers to focus on critical information while ignoring other features.

A clear example can be seen in Christian Wolff's *For Pianist* (1959). In one passage the performer is asked to make a sound which is "as soft as possible", and then determine whether the sound was "inaudible", "as soft as possible" or "louder than as soft as possible" (see ***Figure 1***). The result of this assessment routes the next part of the music to three different sequences of material. Given the comparative nature of this decision, a good model is the *similarity heuristic* which Read and Grushka-Cockayne (2011, p. 25) note

> can be used whenever a classification decision is to be made, when the object or event can be placed into one of two or more categories, and it is possible to assess the similarity of the object or event to members of each category.

So here the pianist must assess the similarity of the amplitude of their resultant sound to the three specified categories. The decision is a simple one in that it isolates one parameter as a basis for the judgment. It is however somewhat indefinite as a criterion and it relies on the subjective judgment of the pianist. The range of amplitudes that might qualify as "as soft as possible" may vary between pianists and pianos, and may be altered by the immediate context. Here the event occurs

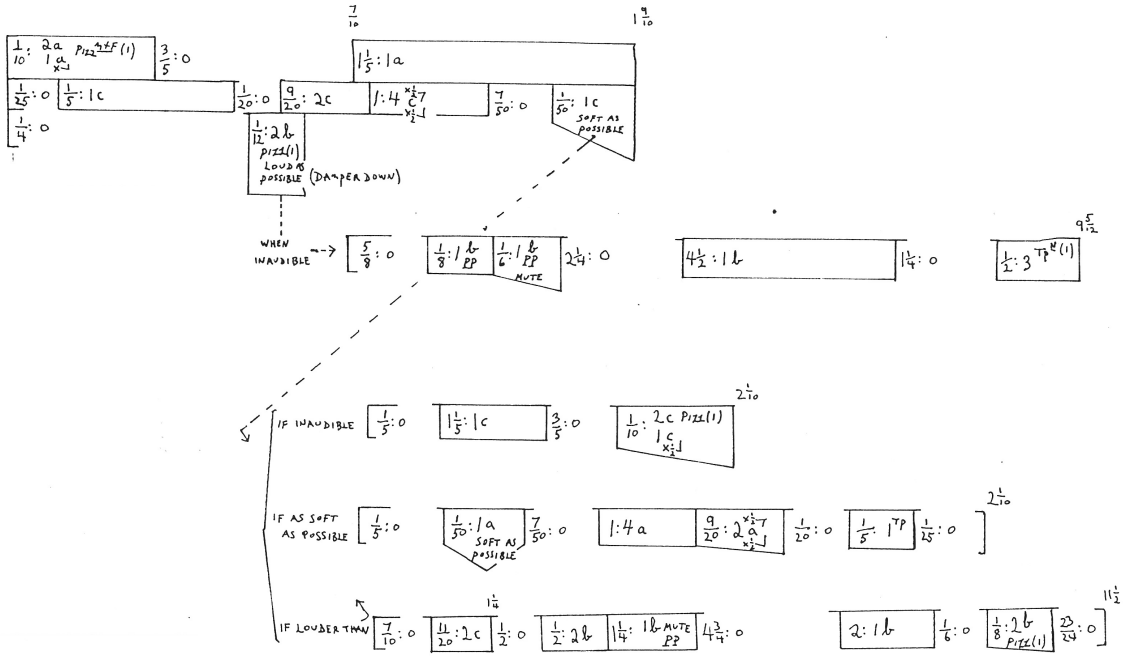

Figure 1: Christian Wolff - *For Pianist* (1959), excerpt

approximately 1.5 seconds after a loud sound which is left to decay and a subsequent constellation of seven other sounds, any of which might alter the perception of amplitude for the cue sound. The heuristic building blocks here are quite straightforward though: the search rule looks for an amplitude cue in the sound; the stopping rule is activated by the assessment of the sound after its production (the search is complete); and the decision rule evaluates the amplitude and triggers the consequent sequence of sounds. The decision is therefore contingent on the perception of the sound and subsequent interpretation of the criterion by the pianist.

In contrast, in Joseph Kudirka's *harmony* (2007) the cues are more explicit (see **Figure 2**). Three tones are sounded, with one tone periodically dropping out. A new tone replaces it, and the rules specify the placing of the tone in relation to the remaining two: either above, between, or below them. Whereas in the Wolff the search rule looks for the relative amplitude of the sound with the consequent subjectivity that creates, in Kudirka's piece it assesses whether the tone that has just stopped was the highest, middle, or lowest of the three that were sounding. While subtle microtonal differentiation in the played pitches or a poor sense of relative pitch might make this task difficult, it is nonetheless more quantifiable than that presented in the Wolff. Kudirka's piece also has a more open decision rule. In the Wolff, the decision is based on the assessment of similarity to the three categories, requiring comparison in order to reach a decision. In *harmony* the player is presented with two options for the new tone and must make a straight choice. So if the stopped tone was the highest, then the new tone should either be the middle or lowest tone. There is no information given as to how this choice should be made however. This reveals a more covert use of decision making where a heuristic is not explicitly encoded in the rules, but rather where one must be employed in order to make the required decision. The player must first "decide how to decide" (Goldstein et al., 2002, p. 183). So in this example the player must choose whether to play a pitch that is between the two that are sounding, or below them. There are two possibilities, and heuristics such as *take-the-first*, the *fluency heuristic* or the *recognition heuristic* may be employed here. Each of these heuristics is a method for selecting between two options. In the recognition heuristic, "if one of two alternatives is recognized and the other is not, then infer that the recognized alternative has the higher value with respect to the criterion" (Gigerenzer & Gaissmaier, 2011, p. 460). Here, if a difficult judgment needs to be made regarding placing a tone between two others–they may be very close together for instance–then it may be that the lower option is selected as it is only this one that is recognized. In take-the-first, the first or only option that comes to mind is selected. Take-the-first is useful in this respect as "part of recognizing or categorizing a situation as typical is to recall what to do in that situation", such that options may "come to mind in order of quality" (Goldstein et al., 2002, p. 177). Here, the ease of playing a lower tone may be thought of first, and therefore selected. With the fluency heuristic "If two objects, a and b, are recognized, and one of two objects is more fluently retrieved, then infer that this object has the higher value with respect to the criterion" (Hertwig, Herzog, Schooler, & Reimer, 2008, p. 1192). This may apply if the possibility of playing either the middle or lower tone is recognized, but that it is potentially easier (more fluent) to play the lower tone, hence more value is attached to that option. In this example, there is no significant sense of utility attached to the decision however. The effectiveness of take-the-first is limited where there are "low costs for making errors" (Goldstein et al., 2002, p. 177). Being caught in the middle of a burglary is not at stake here. Equally, the use of the recognition heuristic may also vary over time and affect the choices of other players as by continuously prioritizing one of the choices it might "assure [it] a place in the recognition memory of others" (Goldstein et al., 2002, p. 178). Success is measured here in relation to the rules of the piece. There are two correct responses in this situation: play the middle or lowest tone, not the highest tone. Players may consider their chance of success is therefore more likely if the lower pitch is played.

harmony

for any number of players

Three tones of differing pitch enter and sound together.
One of these tones drops out, and a new tone enters.

If the tone that stopped was the highest of the three sounding tones, the new tone should either be in between (in regards to pitch) the two remaining tones, or the lowest tone.
If the tone that stopped was the middle tone, the new tone should be either the highest or the lowest of the three tones.
If the tone that stopped was the lowest, the new tone should be the highest, or middle pitch.
Then one of these three tones may drop out, etc.

This process may continue for as long as the players desire.

2007

Figure 2: Joseph Kudirka - *harmony* (2007)

all voices are heard (2015)

Each player needs a large number of instruments and/or objects capable of producing sustained sounds. Every player should have an identical collection of instruments and/or objects.

The aim is to reach group *consensus*.
Consensus is achieved by all contributing players playing a *statement* in unison such that they are in agreement as to its uniformity.
Players must determine if the similarity is sufficient to constitute consensus.
When consensus is reached, the *sequence* is complete.
A performance may comprise any number of such sequences.

A sequence comprises a series of statements.
One player cues the beginning of each statement.
At the first cue, all players play their opening *material*.
At the second cue, and on each subsequent cue until consensus is reached, players may do one of the following:

1. play the same material as that which they played at the previous cue
2. play material that matches what another player played at the previous cue
3. play something new
4. remain silent

The material comprises any configuration of short sounds played on the available instruments and/or objects. The material may comprise one or more sounds.

If a player chooses to remain silent for a statement, that player takes no further part in that sequence, but may join in for the next sequence.

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Figure 3: James Saunders - *all voices are heard* (2015)

This question of utility is central to the use of decision-making processes in rule-based compositions. While the outcomes of decisions in performance will not determine anything as significant as, for example, whether someone has had a heart attack or if it is advisable to get married (Gigerenzer & Todd, 2001, pp. 3-8), they are important within the context of the piece. By not following the rules, the piece is not realized according to the composer's intent, however open the result might be. This is a common problem in realizations of open scores, where flexibility can lead to ambivalence for the outcome where errors may not be noticeable. One way to counteract this is to give value to the outcome of the decision in a way that is apparent to observers.

I attempt to do this in my piece *all voices are heard* (2015), where the results of players' decisions become apparent to listeners (see **Figure 3**). The piece models consensus decision-making, best known as the means through which Quaker meetings are conducted. In the piece, players simultaneously play a sequence of sounds chosen from a limited set of sources to which all have access. This event repeats, with players electing each time to undertake one of four actions:

1. play the same material as that which they played on the previous downbeat
2. play material that matches what another player played on the previous downbeat
3. play something new
4. remain silent

The aim is to achieve consensus, defined here as all players playing the same sound "in unison such that they are in agreement as to its uniformity" (or remaining silent). The degree of similarity is negotiable however, opening up the process to different levels of rigour in the application of this criterion. So two whistle sounds might be acceptable for one player, whereas two C sharp whistle sounds might be required by another, while the C sharp whistles with matched duration, envelope and timbral distortion might be necessary for a third player. This criterion is negotiated non-verbally by the players.

The building blocks in *all voices are heard* focus on developing the best strategy to achieve group consensus in a future state of the piece. The search rule requires players to assess what the other players are doing. The stopping rule activates once this assessment has been made, and the decision rule articulates the response by each player in the next event that is most likely to promote consensus. There is however more autonomy here as a number of different strategies are valid, and players may exert more agency in the decision-making process. So for example, one player might decide that they want all other players to conform to their sound and only play option 1. Conversely another player might always try to conform to the majority sound, aiming to reinforce that to achieve consensus and play only option 2. In both cases the players are trying to achieve the same aim, but their strategies differ and are evidenced by the decisions they make. This may derive from an application of the take-the-best heuristic. Searching through the current texture and checking each of the four decisions in order until a satisfactory match is made would present a workable strategy.

A rank ordering of these decisions might be: 1. remain silent; 2. play matching material; 3. play the same material; 4. play something new. These will promote consensus with decreasing likelihood. In *all voices are heard* players' decisions must, therefore, take into account both the stated aim of the process and the likely responses of the other players. This suggests a game situation, given the presence of an interactive goal-directed challenge with conflicting competitors that creates meaning (Costikyan, 2002; Crawford, 2003). Both utility, with its consequent potential for analysis, and playfulness may emerge.

IV. CONCLUSION

The examples presented here suggest some possibilities for embodying heuristics in rule-based compositions. In the Wolff a subjective assessment of similarity forces a choice from three possibilities. In the Kudirka there is a free choice from two options, inflected by the complexity of the context. In my piece the decision is governed by the strategy that, in each player's view, is most likely to attain the stated goal. These examples show some of the possible ways in which heuristics and decision-making processes more generally are embodied within some rule-based compositions. There seems to be two principal approaches: either to encode a specific heuristic in the rules themselves, or to present decision-making scenarios that require performers to establish a way to make decisions. While there are perhaps no explicit examples of the former as interdisciplinary collaboration between composers and heuristics researchers is currently under-developed, examples such as the Wolff demonstrate that such approaches have been used intuitively in the past. The second approach is more common, with many rule-based compositions presenting a series of decisions that performers must make, such as in the Kudirka and my piece. Here there is great scope for further consideration of the ways performers might make these decisions, generating a better understanding of such behaviours as a means to inform creative practice.

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REFERENCES

Binmore, K. (2007). Rational Decisions in Large Worlds. *Annales d'Économie et de Statistique*, (86), 25–41. http://doi.org/10.2307/20079192

Costikyan, G. (2002). I Have No Words & I Must Design: Toward a Critical Vocabulary for Games. In *Computer Games and Digital Cultures Conference Proceedings*. Tampere University Press. Retrieved from http://www.digra.org/wp-content/uploads/digital-library/05164.51146.pdf

Crawford, C. (2003). *Chris Crawford on Game Design*. Thousand Oaks, CA: New Riders.

Garcia-Retamero, R., & Dhami, M. K. (2009). Take-the-best in expert-novice decision strategies for residential burglary. *Psychonomic Bulletin & Review*, *16*(1), 163–169. http://doi.org/10.3758/PBR.16.1.163

Gigerenzer, G., & Gaissmaier, W. (2011). *Heuristic Decision Making* (SSRN Scholarly Paper No. ID 1722019). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=1722019

Gigerenzer, G., Selten, R., & Dahlem Workshop. (2002). *Bounded rationality: the adaptive toolbox*. Cambridge, Mass.: MIT Press.

Gigerenzer, G., & Todd, P. M. (2001). Fast and frugal heuristics: the adaptive toolbox. In G. Gigerenzer & P. M. Todd (Eds.), *Simple heuristics that make us smart* (pp. 3–34). Oxford: Oxford Univ. Press.

Gilovich, T., Griffin, D. W., & Kahneman, D. (2009). *Heuristics and biases: the psychology of intuitive judgment*. Cambridge: Cambridge Univ. Press.

Goldstein, D. G., Gigerenzer, G., Hogarth, R. M., Kacelnik, A., Kareev, Y., Klein, G., Schlag, K. H. (2002). Why and when do simple heuristics work? In G. Gigerenzer, R. Selten, & Dahlem Workshop (Eds.), *Bounded rationality: the adaptive toolbox* (pp. 173–190). Cambridge, Mass.: MIT Press.

Hertwig, R., Herzog, S. M., Schooler, L. J., & Reimer, T. (2008). Fluency heuristic: A model of how the mind exploits a by-product of information retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(5), 1191–1206. http://doi.org/10.1037/a0013025

Kahneman, D., Slovic, P., & Tversky, A. (1982). *Judgment under uncertainty: heuristics and biases*. Cambridge: Cambridge Univ. Press.

Read, D., & Grushka-Cockayne, Y. (2011). The similarity heuristic. *Journal of Behavioral Decision Making*, *24*(1), 23–46. http://doi.org/10.1002/bdm.679

Selten, R. (2002). What is bounded rationality? In G. Gigerenzer, R. Selten, & Dahlem Workshop (Eds.), *Bounded rationality: the adaptive toolbox* (pp. 13–36). Cambridge, Mass.: MIT Press.

Shah, A. K., & Oppenheimer, D. M. (2008). Heuristics made easy: An effort-reduction framework. *Psychological Bulletin*, *134*(2), 207–222. http://doi.org/10.1037/0033-2909.134.2.207

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, *63*(2), 129–138. http://doi.org/10.1037/h0042769