Spectator Understanding of Error in Performance

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Abstract
The development of computer-based devices for music control has created a need to study how spectators understand new performance technologies and practices. As a part of a larger project examining how interactions with technology can be communicated to spectators, we present a model of a spectator’s understanding of error by a performer. This model is broadly applicable throughout HCI, as interactions with technology are increasingly public and spectatorship is becoming more common.

Keywords
Spectator, performance, music controller, error.

ACM Classification Keywords
H5.5. Sound and Music Computing: Methodologies and Techniques; H5.2. User Interfaces: Theory and Methods

Introduction
Musical performances are ultimately staged for the benefit of an audience of spectators, therefore designers creating new performative interactions need to address both the performer-system interaction and a spectator’s understanding of that interaction (performance). This project addresses the spectator’s cognition of interaction between a performer and an
interactive computer system with primary focus on new digital musical instruments. As most computing systems are intended for individual or collaborative users, there has previously been relatively little focus on the role of spectators in HCI.

The recent proliferation of inexpensive sensing and embedded computing technologies has led to a surge in the development of digital music controllers by composers, performers and designers. The New Interfaces for Musical Expression (NIME) field that has emerged as a result has tended to be rooted in practice. While this is certainly a valid methodology, little time is given to studying how spectators understand these new and often radically divergent performance practices. Within the NIME literature, focus has remained on development of new performance technologies with little regard for the spectator’s understanding of performance or how this should influence design. Dobrian addressed the issue of expression in new instruments, suggesting design paradigms to facilitate virtuosity though gesture capture and sound mapping techniques [7]. However, the mechanisms by which spectators assess skill, expression or style remain largely undefined. In general, NIME has adopted a traditional view of musical expression as a set of undefined extra-musical quantities contained in a work or a performance, without considering the audience’s role within a larger ecology [12].

Outside of music, Benford touched on the role of the spectator in HCI applications, proposing a framework for sensor-based interaction based on classification of the user’s actions [4]. Reeves created a taxonomy for designers relating the transparency of an interaction to the performer’s and audience’s cognition of the system [20]. Benford’s and Reeves’s efforts were aimed at the spectator’s comprehension of mapping of input to output, without considering how this affects an understanding of human performance. In contrast to the cognitive approach of Norman’s seven stages of execution [15], Bellotti defined five issues for designers of interactive sensing systems in terms of communication [3]. These issues—Address, Attention, Action, Alignment and Accident—concern communication between a user and a computer system. While we take a fundamentally interdisciplinary approach, drawing also on cognitive psychology and neuroscience, Bellotti’s communication perspective was considered to better reflect the ecological realities of performative interactions. Reconsidering these from a spectator’s perspective forms the basis of this project:

- **Address**: How does the spectator know that the performer is directing communication to the system?
- **Attention**: How does the spectator know that the system is responding to the performer?
- **Action**: How does the spectator think the user controls the system?
- **Alignment**: How does the spectator know that the system is doing the right thing?
- **Accident**: How does the spectator know when the performer (or the system) has made a mistake?

The initial stage of the project addresses Accident: How the spectator forms an understanding of error between a performer and an interactive system, how this affects the spectator’s assessment of performance (including success and skill) and how this understanding can inform design of future interactions.
Error and Mental Models
The study of error in HCI research generally focuses on why, how and where errors occur. This includes determining what is wrong with the design of the interactive system [15, 17, 20], or how the user's model of the system or mode of interaction with the system has initiated errors in communication [11, 18, 19, 23]. These approaches focus on the relationship between a user (performer) and a computer, yet they provide a basis for understanding how a spectator understands error. It is accepted that an error only occurs through the non-attainment of an attainable goal [24]. Therefore, we define the level of error as the (continuous) difference between the performer's intention and the result of their actions. Distinct from the actual error, the spectator's understanding of the error can then be defined as the difference between the spectator's understanding of the performer's intention and the spectator's understanding of the result.

Research in neuroscience and cognitive psychology into perception of action, perception of intention and expectation [2, 13, 14, 22] shows that intention is the formation of a conscious plan for future behavior, and intention judgment is based on knowledge and perception of physical actions [22]. Expectation is the estimation of the likelihood that specified future behavior will be performed [22]. Expectation is based on cognitive judgment and generalization from past behavior [2]. These definitions can then be applied to understand the spectator's assessment of performer intention and their expectation of performance. Furthermore, studies of expectation and its role in the perception of music show that expectation is a factor in spectators' perception, directly affecting lower level sensory processes [13].

Most HCI research accepts that a user forms a mental model of a system during interaction in order to understand how the system works. Defined as "...a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure maintains the perceived structure of that system," [8] a mental model forms the basis for a user's interaction with the system, directly affecting the ability to perform problem solving [21]. We assume that a spectator observing an interaction similarly forms a mental model of the interaction and uses this model to inform judgments of the performer's actions such as error and skill [6, 21]. Previous work in perception of music is primarily concerned with spectators' emotional responses [1, 13], rather than their ability to model the interaction.

The spectator's understanding of the performer's intention, their knowledge and expectation of actions, and perception of the result contribute to the spectator's understanding of error. These elements form the framework for the following model of spectator understanding of performer error.

Model of Spectator Understanding of Error
Though the model (figure 1) was conceived with music controllers in mind, it is sufficiently general to model any 'performance' situation such as traditional music, sports or learning an interaction through observation. Dark (red) rectangular boxes show the kinds of errors that may arise. The magnitude of error is represented by the length of the line on which they sit—the distance between the connected elements. E.g. If the spectator's understanding of intention is very similar to the performer's intention, these elements would sit close together, the magnitude of the error in perception of...
intention will be minimal. Although the model incorporates many elements that rely on continuous feedback (e.g. mental model, experience, expectation), this is assumed to operate at a lower level, outside of this model. The model can be considered to represent a single ‘instance’ or ‘event’ in a performance: a baseball batter swinging at a pitch or a drummer playing a fill.

**Intention, Result and Perception**

The performer intention is the performer’s conscious plan for future action [22]. The spectator understanding of intention describes what the spectator thinks the performer wants to do [2] based on the perception of actions [22], nonconscious simulation of perceived action, and knowledge [6]. The result is the outcome of the performer’s actions, guided by their intentions. The spectator understanding of result is therefore the product of the spectator’s perception (what they think the performer wanted to happen & what they saw happen) and feed forward information (what they think should have happened & what they were expecting to happen). Perception directly facilitates understanding by mediating the flow of information from the environment to the spectator. We consider perception to be the inverse impedance of this transfer of information, influenced by attention [11] (incorporating arousal [13]), sensory perception [16] and expectation (heightening low level sensory processes [13]).

**Feed Forward**

Feed forward contains the spectator’s knowledge and expectation. Context (knowledge of the scenario/situation/interaction) and experience (tacit/embodied knowledge) are based on past exposure and learning, informing the spectator’s higher-level mental model of the interaction [21]. The mental model represents the spectator’s understanding of how the interaction works and how the component parts influence each other [9]. Expectation, the spectator’s prediction of what the performer will do regardless of perceived intention [2], is based on past experience [22], imagination [13], the perception of actions [5] and knowledge. It is likely that the spectator will form mental models based on generalisations which may be inaccurate due to inadequate sensory information, inappropriate attention distribution [11] and lack of knowledge [15]. This may lead to malformed mental models that are valid for parts of the interaction but do not reflect the intricacies of the interaction as a whole [11], resulting in inaccurate error assessment due to misunderstanding or possibly misperception of the intention or result.

**Error**

The overall spectator understanding of error is a product of the individual elements of error: Error in
A spectator watching a 5-year-old play a piano concerto may expect the performer to make mistakes. This expected error informs perception and understanding of the result, mitigating the understood error even though the result is far from the performer's intention. Watching an expert performer playing the same piece, the spectator would expect a perfect performance based on knowledge and experience of the performer. Mistakes would be understood as error in performance.

A baseball fan watching a veteran power-hitter against a rookie pitcher may expect the batter to try to hit a home run. If the batter gets out but hits a sacrifice bunt to try to advance another base runner, a naïve spectator may think this was an error. This would be an error in perception of intention, leading to a high understood error in performance, even though there was actually no performer error by the batter. If the spectator had incorrect knowledge of the rules of baseball and didn’t perceive that the batter was out, this would be an error in perception of result.

Discussion and Future Work

This model describes the locations and sources of a spectator’s understanding of error. Literature in new musical instruments demands interfaces that allow for greater skill and virtuosity [7]. Spectators’ ability to make such assessments hinges greatly on their understanding of when a performer has made an error. This issue is often simplistically reduced to a vague notion of transparency [10]. However, we have shown that understanding error (and assessing skill) depends on a rich set of personal and environmental factors. This model can therefore inform the design of skillful or virtuosic musical interactions by better communicating error. We expect this research will also be useful in informing the design of systems where users learn through observation of other users. Such public technologies are becoming ubiquitous: self-checkout machines in markets, ticket kiosks, and mobile phones.

Future research will test this model through design, performance and experimental research methods. Some of the other four aspects of Bellotti’s framework are encapsulated within components of the model (e.g. the spectator’s understanding of action relates to the formation a mental model), and these are therefore being examined in parallel. Error provides a natural starting point, as it is arguably the highest-level and most elemental aspect of a spectator’s understanding of performance: judgments of right and wrong.
References


