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SCIENCE DIRECT
Applied Developmental Psychology 25 (2004) 729–740
Applied Developmental Psychology

Understanding media development: A framework and case study

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Abstract

The ongoing evolution of communications technologies and systems creates significant challenges for any effort to understand the role of media in the lives of children and adolescents. The dominant paradigm in studying the relationship between children and media has been one of media effects. However, we propose a reciprocal relationship in which human capabilities and motivation affect the development of media, while media affect human development. In order to investigate this reciprocal relationship, we need not only theories of human development (which are already well established); we also need a theoretical framework for media development, one which has a strong human factors component to it. Without such a framework, the media side of our developmental research will be limited to mere description of a particular local media practice at a particular moment. The purpose of this paper is to sketch part of such a framework and offer an example of its application in a study of the evolution of interactive games.

Keywords: Media development; Video game studies; Children and media; Media perception and cognition; Interactivity

1. Introduction

The ongoing evolution of communications technologies and systems creates significant challenges for any effort to understand the role of media in children's lives. For example, as Scribner and Cole (1981) have argued, even such established and institutionalized technologies as script continue to be organized and reorganized in new ways within different cultures, with the consequence that writing and print do not have uniform consequences for learning and cognitive growth. Hence, even to understand

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0193-3973/$ - see front matter
doi:10.1016/j.appdev.2004.09.010

conventional literacy and its acquisition, one must understand the evolving local culture of text within which individual cognition and competence develop.

This challenge is even greater for studies of the impact of interactive communications on their users. We are now in a period of extremely rapid media evolution as a result of advances in information and communications technologies. The ongoing transformation of the entire range of communications media in the current environment is reflected in both the explosive development of new media technologies and increasing media convergence. As specific technologies evolve, their properties (and therefore their uses and effects) can shift—so, for example, the "interactivity" of interactive media has changed substantially over the past 40 years. Digital convergence creates opportunities for content to be delivered through multiple outlets, making it more difficult to track and assess the effects of any particular medium.

Our research question is positioned at the nexus of these dynamic changes in media and their uses. We are interested in learning what interactive media contribute to media experiences, and specifically how interactivity contributes to audience engagement, learning, and growth, and most especially to children's learning and growth. We ask this question at a moment when interactivity is itself evolving, and in which the market and uses for interactive media are still forming. Therefore, to fully answer our questions requires a new kind of theoretical framework: a theory of how media and humans dynamically accommodate to each other through practice. Without such a theory, any particular study of media effects will, on the media side, be limited to mere description of a particular local practice at a particular moment. The purpose of this paper is to sketch part of a framework for understanding media development and socialization and offer an example of its application in a study of the evolution of interactive games.

2. Interactive media: A framework for analysis

As we have attempted to understand the nature of interactive media and their uses and effects, we have seen a need to identify or develop new methods for classifying types of interactive media and tracking the evolution of media genres. In this effort, we have found it helpful to have an explicit framework for understanding interactive media as emergent and evolving in response to a community's practices. In this section, we sketch our analytic framework, which has been influenced by Pickering's (1995) analysis of the emergent properties of scientific and engineering practice.

2.1. From enabling technology to infrastructure

Over the past 40 years, developments in computing, networking, and interface/display technologies have been woven together to create a complex tapestry of digitally enhanced media. These developments have been well chronicled in both print (e.g., Akera & Nebeker, 2002) and online sources (e.g., the Digital Technology timeline offered by the Cornell Library at http://www.library.cornell.edu/iris/tutorial/dpm/timeline.pdf).

As they have developed, these enabling technologies have given rise to a changing array of interactive media. In our view, the essence of interactivity is dialogue. Seeing dialogue as the foundation for interactivity is consistent with Meadows' (2002) analysis of behavior in and with interactive systems. Meadows argues that interactive performance proceeds in four steps: (1) observation or assessment; (2) exploration; (3) modification; and (4) reciprocal change. Observation motivates action toward the digital environment; this modifies the state of the environment and produces feedback that in turn modifies the state of the user. This is the human-machine equivalent of dialogue, what Mead (1934) described as a "conversation of gestures."

As Mead (1934) envisioned dialogue, it is a cooperative performance in which agents coordinate their behavioral streams. Moreover, Mead saw behavior as a sequence of gestures, i.e., as discrete significations meant to convey more than literal meaning. In the "conversation of gestures" individuals both act to advance their interests and, based on a process of role-taking, recognize and adapt to the interests of others. They shape their conduct to fit the requirements of the activity in which they are engaged. As theorists such as Goffman (1965) have argued, even everyday tasks like navigation through the environment should be seen as dialogues with seen or even unseen others to whom gestures are being constantly offered in an intricate and coordinated fashion.

To support dialogue, then, a medium must afford opportunities to gesture-to perform or act-and to respond to the gestures of other agents. Performing requires both a mode of action through which gestures can be produced and means of orienting the self and controlling gestures through appropriate feedback. Coordinated performance demands information about the other, so an interactive medium must also support mutual awareness and cooperative problem-solving. Performance in any medium is a skilled activity predicated on mastery of the medium—for example, using a telephone is based on holistic mastery of an entire, integrated telecommunications system, not on the component technologies of the telephone.

However, communication systems do not evolve in a uniform or integrated fashion. As digital technologies advance, component technologies can afford new and more acceptable ways to meet the requirements of mediated dialogue or some particular activity being accomplished through dialogue. The past four decades have seen continuous advances in the component technologies that enhance interactivity.

Interestingly, many interactive media genres arose early in the history of interactive media, but have been invented and reinvented as the leading edge of computing and network technology advanced. For example, an early system to support interactive learning and communication, PLATO, was developed beginning in the 1960s at the University of Illinois. It was a complete interactive communication system, in which many current interactive genres were first prototyped, including chat, threaded discussions/bulletin boards, virtual classroom tools, and multi-user games. However, PLATO was assembled using computer (mainframe) and network (local network) technologies that preceded the personal computer and Internet.

One lesson to be learned from PLATO is that complete and successful interactive systems can be created as prototypes, but to be useful as communication media they must be institutionalized to the point that they can be taken for granted. The process of institutionalization often takes decades—for example, many electronic technologies that are now in common use (e.g., radio, telephone, and television) were first prototyped in the second half of the 19th century, but only became sufficiently institutionalized to deliver content to audiences some decades later (Burns, 1999; Douglas, 1997; Winston, 1998). Institutionalization involves the development of policy and practice as well as standardization and dissemination of technology. As Starr (2004) has argued, a host of policy decisions shapes the way in which a medium will take form and be used.

Similarly, as Brown and Duguid (2002) have pointed out, users must develop their social selves and media competencies in ways that address the capabilities and limitations of the technologies they wish to use—the user is a construction of the technology, just as the technology is a construction of the user.

Brown and Duguid's (1994) well-known example is the persona one is urged to assume as a Macintosh user, explicated through their exquisite analysis of how opening the Macintosh package began the process of instructing the user. Closer to our own interest, one might point to the shifting persona of the computer gamer—initially in PLATO a communally oriented programmer, then in the era of console gaming an obsessed social isolate, and now in the era of Internet-based multi-player games a socially and technically skilled player, often a middle-aged woman.

In short, the shape taken by a communications technology will reflect the confluence of a set of enabling technologies (a medium), the imagined uses of the medium, policies governing access and use, diffusion and adoption of the medium within a particular community, and a set of user roles and competencies developed around use of the medium for a community's purposes.

Pickering (1995), in discussing similar contingencies in the institutionalization of scientific procedures, theories, and facts, felicitously referred to the standardization of complex socio-technical systems as "the mangle of practice." Technologies, uses, and users stabilize in relationship to one another in ways that are to some extent accidents of co-occurrence but which are nonetheless conjoined in a logic of practice. They are mobilized in concert but may not be seamlessly integrated (indeed, significant fissures or contradictions may exist within the system). As such systems stabilize, they move from demo to infrastructure, from the awkward and unstable prototype to a "communication channel" that comes "ready to hand" and is taken for granted by a community of users.

Many existing communications systems and institutions have been destabilized by developments in digital technology, sometimes because of changes in production or distribution systems (e.g., the digitization of the film industry) and sometimes because of changes in policy or use (e.g., the reconstruction of intellectual property and its affiliated policies and practices). However (as in the case of the PLATO system), communication genres and their users persist and migrate as media platforms shift and change.

Films, sitcoms, pop music songs, and interactive games can be realized and supported by many different infrastructures. Accordingly, our method of analysis begins by identifying major categories of interactive media and their uses, and then considers the ways in which existing technologies resist, and new solutions afford, improvements in use. This helps in understanding how and why media develop in concert with the limitations and capabilities of human learning and development. In our current work, the genre on which we have chosen to focus is interactive computer games.

2.2. The dance of agency

Pickering's (1995) view of "readiness to hand"—the fit between human and "material" agency or instrumentation—differs from the more traditional, human-centered view of usability in emphasizing "the dance of agency," a process in which both human and instrumentation mutually "tune" or shape each other, with neither human nor material agency being seen as determinative.

Key to Pickering's analysis is a view of agency as performative: agency is doing, guided by purpose. Performance, which involves interaction between humans and the beings and instrumentalities around them, is always in some ways easy and other ways challenging; and at least some challenges are experienced as resistances that need to be overcome. Resistance is overcome by accommodation, either by the human or instrumental agencies involved in a performance. Human agents can adapt to a system's constraints, developing skill (which Pickering prefers to conceive as "discipline," the restructuring of an agent's performance in relationship to an activity's demands); likewise, instrumentation can be redesigned to accommodate human limitations, preferences or practices. This process of adjustment stabilizes, at least momentarily, when a satisfactory accommodation is reached.

The case of computer games is especially interesting from the standpoint of understanding the role of agency and resistance in media use and change. Games are meant to be challenging, i.e., to resist the user. As Zehnder (2004) has pointed out, there is a significant amount of learning that must be invested in most 3-D games in order to successfully complete their tasks and levels. Each new game cartridge has its own set of physical 'rules' that must be learned in order to advance (Greenfield, 1984). In many games, one of the first activities is a series of tutorials whereby the player becomes familiar with the game controls and the environment before the actual game begins. But an experienced 3-D gamer will be able to learn the controls and strategies of the new game more rapidly than an inexperienced player, due to their expanded repertoire of skills and experience with similar systems (Greenfield, Brannon, & Lohr, 1994/1996).

In the end, however, the game must sustain the interest of the player with *appropriate* resistance, resistance that promotes rather than reduces the player's interest in acquiring mastery. Successful games are precisely those that focus player activities toward acquiring mastery rather than accommodating to the constraints of the game platform or design, and successful game innovations resolve inappropriate material resistance and enhance player mastery.

2.3. Agency and dialogue

Based on the preceding view of media, Wartella, O'Keefe, and Scantlin (2000) offered an analysis of media socialization (i.e., acculturation to and through media use) aimed at articulating the role of interaction—including interactive media—in "disciplining," or constructing, human agency. Consistent with work by Vygotsky (1962) (for an overview and commentary, see Wertsch, 1991) and contemporary activity theorists such as Cole (1985), Engstrom (1992), and Lave (1988), Wartella et al. (2000) view cognitive growth as the acquisition of situated knowledge and skills. In this view, cognitive structures and skills reflect the accumulation of learned performances, each specific to a particular activity.

The core metaphor for such situated learning is mastery acquired through apprenticeship (Collins, Brown & Newman, 1989; Rogoff, 1990). A novice may initially be unable to perform an activity competently, but in a social situation, performances are organized in a way to include him/her, a process called "scaffolding" (Wood, Bruner & Ross, 1976). This may occur first through observation, then by allowing the apprentice to perform increasingly more complex and responsible tasks, with decreasing support from others, and finally as an autonomous actor. Even when a novice participates "peripherally" in an activity (i.e., by observing or assisting), he or she gains knowledge, skill, and "discipline." With increasing knowledge and skill, the learner is able to take on a greater scope of activity, participate more "centrally" in the activity (i.e., leading or guiding the activity), and function as a more independent learner (Lave & Wenger, 1991).

Theories of dialogue (Bahktin, 1990; Goffman, 1981; Wertsch, 1991) provide an explanation of socialization and interaction in terms of participation in a conversation of gestures (Mead, 1934). Each communication medium is characterized by a method for organizing gestures and responses to them. Such "participation structures" (Levinson, 1993) govern what can occur in the participation space or "floor" in a communicative event. As Wartella et al. (2000) point out, a participation space can be quite complex. Many different kinds of gestures or displays can be produced: text, sound/voice, still pictures/video, animations and visualizations, or representations of the interaction setting (both realistic and imaginative). Different types of spaces can link participants' contributions in different ways; one key differentiator is whether a particular medium uses temporal placement to link contributions ("synchronous" communication) versus another strategy for connecting contributions, such as spatial proximity ("asynchronous" communication, e.g., threaded discussion). Participation spaces also differ in the degree to which they can sustain a sequence of reciprocal gestures. In general, Wartella et al. (2000) hypothesize that a medium is "interactive" when it creates the possibility of display and response dialogue, but the quality of its interactivity is a function of the richness of display possibilities (i.e., the number of sensory modalities employed), the nature of the available response options (in particular, the degree to which synchronous responding is possible), and the ability of the medium to sustain a chain of interaction.

2.4. Summary

This framework leads us to analyze games as dialogues in which players seek mastery by overcoming resistance. Mastery is situated and performative; it is acquired through apprenticeship within a particular activity. Games become engaging to players (and consequently effective in disciplining their agency) to the extent that potentially inappropriate resistance is resolved through accommodation to human users and appropriate resistance is maximized, leading to a challenging but playable game. Resistance arises relative to an existing culture of practice, with expectations about game structures and cultivated skills among expert players. The drive to overcome resistance leads to player development and game evolution.

3. Case study: Point-of-view in video games

Zehnder (2004) applied this framework in a study of the evolution and use of point-of-view (POV) in video games. Following Moszkowicz (2002), he noted that both digital cinema and video games borrow techniques for the simulation of POV from film and television, while also exploring novel possibilities for dimensional perspective. 3-D gaming, in particular, frequently employs cinematic point-of-view while also enabling interactive navigation (control of motion and perspective) and simulated embodiment.

Greenfield (1993) considers the difficulties of navigating through three-dimensional space when it is represented in only two dimensions. Her example is the original *Castle Wolfenstein* (Muse Software, 1981) game, where each screen is a two-dimensional maze representing a room in the Castle. In that game, the player must infer the third (vertical) dimension by understanding that when his or her avatar (i.e., cursor in the shape of a man) exits a two-dimensional maze at a stairway icon, the next screen that pops up will represent a higher or lower floor of the castle (the vertical dimension). The stairway icon is the only visual cue to the vertical dimension. Only expert players understood this cue and formed a three-dimensional representation of the castle that they then could use for navigational purposes (Greenfield, 1993). The limited nature of the two-dimensional screen representation created a strong resistance in the game to navigation.

After computer graphics had developed enough to permit three-dimensional representation, Castle Wolfenstein was released in a three-dimensional version, *Wolfenstein 3-D* (Activision Publishing, 1992). By providing many more cues to the three-dimensional nature of the castle, this new version made it much easier for players to navigate through a three-dimensional virtual space. This change in the Castle Wolfenstein program illustrates how a technological development can overcome an initial resistance, creating a new media form that is better adapted to human capabilities. This example also illustrates the "dance of agency." On the one hand, electronic games develop spatial skills (e.g., Greenfield et al., 1994/1996; Okagaki & Frensch, 1994/1996; Subrahmanyam & Greenfield, 1994/1996). On the other hand, the game environment has developed to more closely resemble the three-dimensional environment in which spatial skills evolved, therefore providing less "resistance" to those skills.

3.1. Navigation, viewpoint, and framing

An important affordance of 3-D technology in gaming, compared to its 2-D counterpart, is the representation of virtual spaces *for the purpose of making navigation easier*. Note, however, that so-called 3-D technology is still presented on a flat two-dimensional screen. As Manovich (2001) and Meadows (2002) aptly remind us, new media share with its predecessor cinema the simulation of a camera in a three-dimensional space. The major difference, Manovich argues, is that in new media such as video games, "the image becomes interactive, that is, it now functions as an interface between a user and a computer or other devices" (p. 183). Furthermore, Manovich asserts, "directing the virtual camera becomes as important as controlling the hero's actions" (p. 84).

What differs from the so-called 2-D representations are the visual cues to the third dimension, such as dynamic real-time shading, cues such as systematic variations in size and shape based on an object's position in a simulated z-axis, or in some cases, simply perspective lines. The addition of depth cues and perspective cues to the two-dimensional representations of three-dimensional space enables digital technology to operate with what Moszkowicz calls *computer vision*, "generating images that not only reproduce a three-dimensional form, but which emulate our experience of moving through that setting" (p. 301). Of crucial importance is the way that 3-D artists have tried to achieve an effect that has intrigued visual artists for generations: "the effect of objects receding into the background" (Moszkowicz, 2002, p. 300).

Zehnder (2004) employed two related cinematic concepts, POV and framing, to understand the role of perspective in interactive games. He examined the use of point-of-view and framing in a sample of popular video games. Zettl (1999) defines POV as "a specific character's perspective, the way a particular character sees the story unfold" (p. 190). Point-of-view "determines *who* the viewer identifies with" and nearly always works in combination with other elements, such as framing, in order to achieve the overall effect (Katz, 1991).

"First person" describes the point-of-view of events from the eyes of a character controlled by the player (see Fig. 1). "First person shooters" are among the most popular of genres, and include such classics as *Wolfenstein 3-D* (Activision, 1992), *Doom* (id Software, 1993), *Quake* (id Software, 1996), and *Goldeneye* (Nintendo, 1997), to name a few. One would expect first-person point-of-view to maximize the identification of viewer and avatar, and this may be a reason why first-person shooters are so popular.

The alternative viewpoint, third-person, provides a view of the game world as distinct from a character's view. For third-person perspectives, Zehnder found three major framing possibilities: restricted, omniscient, and cinematic.

Many games employ a *Third Person Restricted* viewpoint. "Restricted" refers to the presentation of action as it would be seen by an ideal observer, "in the style of narrative most common in Hollywood movies" (Katz, 1991). Some contemporary games utilize *Third Person Restricted-Trailing* POV, where

Fig. 1. First-person point-of-view (ex. *Medal of Honor: Frontline*, EA Games, 2002).

the 'camera' privileges a position directly behind the player's avatar for viewing of all of the action in the space. *BMX XXX* is one example among many of an acrobatic (a.k.a. 'extreme') sport game that relies on a *Third Person Restricted-Trailing* POV.

Other games, such as *The Lord of the Rings, the Two Towers* employ *Third Person Restricted with Cinematic Framing*, where the 'camera' jumps to an idea position for a given scene, and allows the character to move freely along a certain path. Although both involve 'ideal' camera positions, *cinematic* framing is distinguished from other types of third person POV (such as *trailing*) in that the framing is variable and determined by a variety of pre-defined and directed states by the game designer. For an early example of this technique, consider the different behavior of the background in the games *Super Mario Brothers* (Nintendo, 1985) and *Faxanadu* (HudsonSoft, 1989): in the former, the background scrolls right-to-left on the screen as Mario moves left-to-right, while in *Faxanadu* the background holds its position until the character moves far enough to the edge of the screen, when it rapidly scrolls ahead to the next 'ideal' position.

Finally, some games, such as *the Sims* (EA, 2000) and *Black and White* (EA, 2001) give the player a *Third Person Omniscient* POV with some degree of control over what is seen, when, and from what distance, sometimes including the ability to see the game from the perspective of another character or player (see Fig. 2). This control is analogous to being able to move a camera over a scene, as well as being able to adjust the camera lens to zoom in and out. Moreover, in a game like *the Sims*, the player is made aware of the 'internal' state of the characters (called Sims) by meters representing the needs and desires of all the Sims the player has created.

3.2. Action, embodiment, and point-of-view

Virtual reality, no matter how advanced visually or aurally, remains numb to the complex positional cues our body receives from the physical extremities. *Proprioception* (a.k.a. kinesthetics) describes the sense of body orientation and movement that is made possible by stretch receptors in the joints and muscles which relay positional information to our brains. This sense endows human beings with the ability to do such things as walk without looking at our feet and touch our nose with our eyes closed.

Fig. 2. Third-person omniscient (ex. *The Sims*, EA Games, 2000).

In action games, the type of dimensional perspective offered, including both point-of-view and the nature of the control interface, is often a compensation for the lack of proprioceptive information available to a player. Many complex game actions, such as flipping, jumping or walking, are extremely difficult to execute without proprioceptive cues. Games can accommodate to the resistance this creates by providing visual substitutes for proprioceptive information. For example, many games that require full-body actions such as flipping and twirling employ a third-person or omniscient perspective in order to make the action easier to perceive, especially in games that involve rapid motion.

This is well exemplified by Zehnder's (2004) analysis of *Tony Hawk Pro Skater 4*, which involves complex positional tasks such as flipping, twirling, jumping, sliding, kicking, handstands, and other acrobatic maneuvers on a skateboard. Such complex acrobatics would be nearly impossible from a solely first-person perspective, especially since there is no way for the player to 'sense' the position of their feet and other extremities. The game's *Third Person Trailing* POV is an effective accommodation to the resistance or challenge created by the lack of proprioceptive cues. In this use of viewpoint, the skateboard becomes another type of extremity, for which it is crucial that the rider 'know' her position in relation to the ground and the feet at all times. *Third-person trailing* POV enables the game player to see the skater's entire body and board, thus enabling difficult maneuvers in the absence of proprioceptive cues.

3.3. Further developments in perspective and embodiment

While manipulation of viewpoint can help in overcoming the resistance to effective action created by a lack of proprioceptive information, the inadequacy of visual information as a substitute for proprioception is signaled by the ongoing development of strategies for embodying players. The current 3-D game market offers various strategies for embodiment, ranging from the construction of 'fleshy' characters, bodies that show their injuries, characters that get tired, as well as devices such as the arm reaching from the bottom-center of the frame holding a gun for the player of a first-person shooter game. New techniques for the rendering of flesh are closely related to the rendering of many types of deformable objects, including clothing that folds and moves in response to the wind or a character's movements; wobbling breast, belly or thigh; any type of gelatinous object; or rope that stretches and swings (Bowell, 2002). While many of these cues are undoubtedly included in order to enhance the "reality effect" (Manovich, 2001) of the video game, increasingly these cues are also able to provide additional information to the player to about the dimensions, state, and relative positioning of their virtual body in the virtual space.

Many games incorporate embodiment by representing the character's state of injury or exhaustion through the actual body of the character. An extremely advanced use of this technique is that of *The Getaway* (Sony, 2002); where the character actually limps, holds his arm, and has blood begin to appear on his clothing to indicate his injuries. *Wolfensten 3-D* (Activision, 1992) utilizes an earlier version of this technique by representing the character's injuries by an icon of the character's torso, that grows increasingly disfigured and bloody as the character is injured. Characters that tire from over-exertion (*Grand Theft Auto: Vice City*, Rockstar Games 2002) are another variation on this technique of embodiment. In all three of these examples, the player must learn to incorporate this information about the virtual character's physical state in order to successfully complete the target game activities. This additional layer of 'realism' has a profound effect both on the identification of the player with their virtual character, and on the type and degree of investment the player must make in learning the logic of the interface and its accompanying system of codes.

That embodiment has an effect on the perspective of the player or the player's control over the game demonstrates how, increasingly, the techniques of POV and embodiment in 3-D games are semiotically central to the nature of the human–machine communication. As Moszkowicz (2002) suggests, "...technology and modes of perception are entirely interrelated, yet in the world of popular culture, methods of visualization have a nasty habit of being obliterated by other (over-privileged) aspects of technical achievement."

Our case study of POV in video games also indicates that perceptual resistances to human–computer interaction are not necessarily generated by the technique itself, but by the deployment of a representational technique for a given activity. For example, although First-person POV might be useful for precise aiming, character-to-player interaction, or the careful examination of game visuals, it is certainly not the optimal POV for all possible gaming activities. Third-person restricted POV would likely prove more effective for tasks such as climbing a wall, performing a complex maneuver involving the character's extremities, or coordinating multiple game characters/objects. This suggests that although some resistances are bound by the state-of-the art, others are intentionally deployed by the interface designer in order to balance the level of difficulty of a given task.

4. Conclusion

Changes in the way of seeing, or the tools of seeing—changes in the possible points of view—impact the way individuals understand the world. In 3-D visualization, the borders of images are simply the horizon of what can be seen from a point-of-view; in most cases, there is an expectation of other possible views to the same object. By playing video games, some images have new meaning, such as horizons serving as references that are important for the purposes of navigation. In the shift from 2-D to 3-D, the purpose, cognitive implications, and the tools of navigation undergo a process of reciprocal transformation until the entire system becomes somewhat normalized or a new technology is introduced. This is very similar to the process of innovation in science as described by Pickering (1995), a mangle of practice in which human and machine agency intertwine.

The process of technical development, in which inappropriate material resistance is overcome through development of improved visualization and information, is companion to the process of human media socialization and development, in which individuals master the specific forms of agency required to be players. Understanding this reciprocal "dance of agency" offers a new window into the impact of interactive technologies on humans, machines, and the cultures they create.

Acknowledgements

This research was supported by Award #0125592 from the National Science Foundation for a project entitled COLLABORATIVE RESEARCH/CRI: Children's Digital Media Centers.

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