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Inputs and Outputs: Engagement in Digital Media from the Maker's Perspective

> Arts research needs to change direction, to look outwards, and investigate the audience not the texts. It needs to link up with sociology and psychology and public health, and create a body of knowledge about what the arts actually do to people. Until that happens, we cannot even pretend that we are taking the arts seriously. (Carey, 2006)

Abstract

Many academic fields would benefit from an aggregation of technologies that could objectively measure engagement on a moment-by-moment basis. To develop this methodology, subjective responses to stimuli must be shown to correlate with the component technologies, such as motion capture or psychophysiology. Subjective scales for engagement often fail to segregate the measurement of causes (inputs to the audience) and effects (outputs from the audience). This lack of separation can obscure appropriate inferences in the relationship between cause and effect. Inputs to the audience are scripted, and are controllable by the maker. Outputs are engendered in the end-user by the scripted experience, and outputs can include both mental states (e.g.

satisfaction) and physical activities (such as heart rate). Outputs can occur during the stimulus and subsequently (e.g. learning). Inputs can be maximised a priori by design, but to optimise outputs from the end-user one needs an empirical process, because outputs depend on the interpretive processes of the end-user. Outputs are highly dependent on audience and context. In instruments used in experiments assessing the relationship between inputs and outputs, it is critical that controllable inputs to the end-user must not be conflated with outputs engendered in the end-user.

Introduction: Ambiguous Terminology

There is a long discourse in the humanities investigating how a work of art affects the audience, represented predominantly by audience reception studies (Alasuutari, 1999; Garner, 2010; Livingstone, 1998). Engagement is considered an important goal in the fields of education (Oakeshott, 1998; Reiss & Ruthven, 2011), digital media (Overbeeke et al., 2003), politics (Heyman, 2011), sales (Ryan & Jones, 2011), arts (Berleant, 1993), and science (Thorpe & Gregory, 2010; Bowler et al., 2012). There are many related engagement-like constructs (centred on the contrast between being interested versus bored), including presence, cognitive absorption, involvement, and immersion. The goal of our laboratory is to contribute to the understanding of how different experiences—which we call stimuli—engender engagement (among other responses) in their audiences or participants. The purpose of this research programme is to be able to measure fractions or 'atoms' of engagement, so that one might theoretically be able to measure the progression of interactional narratives.

Our cross-disciplinary approach is to empirically validate the use of scientific methods to measure the effects of stimuli, such as music and art. We are looking to measure causes, effects and the relationship between them, so our basic research question is, 'What causes people to engage or disengage with an experience?' To answer this question, we are trying to correlate three types of output measurements: psychophysiology (such as heart rate and electrodermal responses), motion capture, and subjective reporting via questionnaires. Our research has come upon a problem: causes and effects are often conflated in the subjective instruments traditionally used to measure

engagement-like experiences. This means that elements you can control to a high degree are treated on the same level as elements you cannot control (audience responses), and which you at best can elicit or encourage. These traditional questionnaires have been useful in the literature for initially defining experiential aspects of human-computer interaction. However, such questionnaires vastly complicate most attempts to tease apart cause and effect relations. From the web developer's perspective, causes can be controlled, but effects (e.g. heart rate and engagement) cannot be controlled directly.

The Human-Computer Interaction (HCI) field has reinvented a wealth of terminologies to describe and measure the effects of a computer experience (Bargas-Avila & Hornbæk, 2011). In some cases, this nomenclature creates controversy in HCI. For example, the word *immersion* has two distinct meanings attributed to it inside the HCI literature. If a participant in an experimental setting enters an immersive environment, with surround-sound and virtual reality goggles, one could say that the experimenters have created a situation of immersion, i.e. the laboratory provides inputs filling and surrounding all senses, or that the mental state of the participant is immersion, i.e. the participant is fully engrossed in the experience. The former type of immersion is a cause, the latter is an effect. This confusion in nomenclature was made explicit in a paper by Witmer and Singer (1998):

> Though the VE equipment configuration is instrumental in enabling immersion, we do not agree with Slater's view that immersion is an objective description of the VE Technology (Slater et al. 1996). In our view, immersion, like involvement and presence, is something the individual experiences.

While immersion imposed by the experimenter (i.e. an immersive environment) and immersion as mental state sometimes co-occur, they do not always do so. There may be theoretically unexpected divergences between immersive environments and the sensation of being immersed. For example, in 2007 Dow et al. showed that by enhancing the naturalistic or immersive qualities of a game's interface, the engagement (and immersion as mental state) felt by some players was diminished (Dow et al. 2007). This experiment investigated Façade—a real-time, interactive drama, combining autonomous characters, artificial intelligence, and natural language processing to place the player inside a dramatic world. In that world the player is an old friend of Trip

and Grace, and the player is visiting them in their flat, ostensibly for drinks and conversation, but unexpectedly winds up entangled in the dynamics of their troubled marriage. The player can make virtually any conversation with the couple, who will respond appropriately while making barbed comments to each other. The end result, which is never explained to the player, can range from mediating a partial rapprochement between the couple, to being bodily thrown out of their apartment for being rude and insulting.

Dow et al. arranged for their experimental volunteers to use three interfaces. These were: the original desktop 3D version, in which the player can hear the voices of Trip and Grace but must type in his/her own responses; a desktop 3D version where the player's input is speech instead of typed text; and a fully immersive augmented reality (AR) version. In the AR version, the player wore a head-mounted display to create a physical recreation of the Façade apartment, which allowed the player to walk, gesture and speak to the virtual characters Trip and Grace. Contrary to the experimenters' initial expectations, although the more immersive augmented reality interface increased most players' sense of presence over the desktop interaction, heightened presence did not always lead to increased engagement. The immediacy of the interface appears to have interfered with several players' ability to experience the game as a "play space" (Salen & Zimmerman, 2004). These players preferred desktop interaction specifically because it is *less* immersive, making it easier to take on different personas and providing a safe distance from the emotionally charged drama.

In the example of Façade, making the inputs (causes) more immersive led participants to feel in some cases less engagement/immersion as a mental state (an output); that is, more immersive inputs sometimes led to less immersion as output. This highlights one of the potential benefits for making definitions demarcating outputs from inputs. Even though the process of delineation may be imperfect, and there may be some overlap between the terms in certain cases, the process of distinguishing inputs from outputs will allow more robust description and testing of causal relationships. Our goal is not semantic analysis, but to provide a filter for looking at other definitions used to assess HCI experiences. The resulting refinements may be useful for the web developer/maker in assessing and fine-tuning his or her work.

By separating causes and effects, researchers can empirically test the relationship between putative causes and the effects they are seeking. To take a simple example in our laboratory, we would like to test whether physical movement, and the amount of physical movement, could be used as a surrogate indicator for engagement. The advantage of using movement over purely subjective questionnaires is that one could potentially have moment-by-moment information, and this information may be less obscured by 'politeness'. However, it is not immediately obvious how net movement is related to engagement. Some scientists might expect high levels of net movement to be representative of fidgeting, and thus an output representing frustration and disengagement (Kapoor et al., 2007); other theories of engagement would expect high amounts of movement to be associated with arousal by (or entrainment to) the stimulus, and thus be an output representing engagement (Bull, 1987). Many educators suggest that initiating physical movement in the class encourages engagement (Northrup, 2002), in which case physical movement would be more of an input (controlled or scripted by the leader) than an output. Without separating inputs and outputs, the relationship between cause and effect is sometimes difficult to recognise. This is especially true for the relationship between net movement and engagement. One needs to distinguish between levels of movement controlled by the designer (e.g. having a player use a Wii (Bianchi-Berthouze et al., 2007) or asking the class to stand up), and movement as an output (e.g. fidgeting as a sign of disengagement).

Defining Inputs and Outputs

Here are our suggested human-centred definitions for inputs (to the audience) and outputs (emanating from the audience) in HCI. An input is a feature designed or scripted into the experience, and it is mostly controllable by the designer or maker. The colours in a painting are inputs. An input may be directed at a certain kind of end-user (e.g. not colour-blind), but the input does not depend on the response of a specific end-user. Outputs are generally vested most clearly in the end-user (or audience) and cannot be fully controlled by the designer. An output is what the designed experience engenders in the end-user, and depends on what the end-user brings to the

situation (e.g. the end-user's mood or taste in paintings). Outputs include mental states and processes (e.g. learning), and activities both during the stimulus and subsequently. Satisfaction is an archetypal output.

Inputs and outputs are much more clearly delineated in non-interactive experiences such as a book, a musical or a painting (Douglas & Hargadon 2001), so an example from outside HCI may be in order. For a detective novel, the inputs may include a tale of various crimes, descriptions of many characters, plot events occurring at a rapid pace, and an ending that is surprisingly different from other such novels. Outputs (experiences vested in the reader) for the same detective novel might be feelings of apprehension, recollection of the characters' names, sitting still and not talking (while reading), and later telling friends about how good it is. The advantage of attempting to define inputs and outputs, from the maker's perspective, is that it allows one to think in terms of cause and effect.

Causes (controllable inputs) are possible to maximise by design, while maximising outputs (e.g. satisfaction, heart rate, or time spent looking at a web page) typically is performed by an empirical process—which will require more time and resources. This empirical process has been made famous by Google's use of the "A/B test," in which the managerial decision between two designs is determined by splitting live web users between two different versions of a web page and numerically quantifying which page is better at impelling end-users toward the desired online output (Christian 2012). While outputs are ultimately what all developers (and funders) are supposed to be seeking, the myriad tiny decisions in a complete design process means that most inputs need to be decided upon expeditiously without experiments, as made clear by ex-Google designer Douglas Bowman on his blog the day he left the company (2009):

> Yes, it's true that a team at Google couldn't decide between two blues, so they're testing 41 shades between each blue to see which one performs better. I had a recent debate over whether a border should be 3, 4 or 5 pixels wide, and was asked to prove my case. I can't operate in an environment like that. I've grown tired of debating such minuscule design decisions. There are more exciting design problems in this world to tackle.

Interactivity

There will be difficulties in attempting to universally classify every single component of an experience as purely an input to the audience or an output from them. Where do you classify factors that seem to function as both inputs and outputs, such as interactivity? A traditional input occurs before the output, but with interactivity, all time-based relationships between inputs and outputs can be in flux. An example of interactivity that is both a cause and an effect is the baby naming tool at babycenter.com, a website directed toward new parents and parents-to-be with a world-wide audience of 39 million parents or parents-to-be every month. This tool allows the end-user to search a database of 16,000 names from all over the world, according to gender, meaning, origin, first letter or first syllable. In addition, there is a 'lucky dip' feature that makes random suggestions, and an option to create custom polls to send out to friends and relatives for voting on their favourite names. Parents-to-be or new parents using this web site spend far more time per page than the average time spent looking at a typical web page (33 seconds) (Filloux & Gassée, 2010).

In this case of interactivity, the separation of inputs from outputs—allowing for the elucidation of the causal connection between them—can be clarified with extant terminology. Design features that allow for interaction (i.e. inputs) can be called *affordances* (Gibson, 1979; Norman, 1988). In the case of the baby naming tool, the affordances are those aspects of interactivity created by the web development team, which include the database of names and the search facility. When interactivity is being classified as a measurable output of the end-user's commitment, it can be called *compliance*. All the time spent by parents-to-be with the baby naming tool is a form of compliance. This time spent engaging with the web site—which holds the end-user's attention and prevents them from navigating away—creates a relationship between the end-user and the web site (and possibly the brand). Although the interaction between the parents and the tool can be seen as a holistic system of interactivity, the commercial goal is concerned with designing the affordances to maximise user compliance.

Compliance usually takes the form of investment of time, and there is a classic Internet banner ad based on this investment in time. The "Mr. Pringle can-on-hand banner ad" (Banner Lovers Society, 2009) by Bridge Worldwide

won a gold Cyber Lion from the Cannes International Festival of Creativity in 2009 (Kiefaber, 2009). In this atypical banner ad (which does not even forward the end-user to the sponsor's website), the end-user is encouraged to repeatedly click on the Mr Pringle character; after each click, Mr. Pringle humorously adds to the one-sided conversation. The end-user keeps on clicking to elicit another of Mr Pringle's wacky and self-referential statements, and the joke becomes explicit after about five minutes of clicking when Mr. Pringle asks, "Do you do this with all the other banner ads, or do we have something special?".

The example of Mr. Pringle clearly illustrates how interactivity can be divided into affordances (when Mr. Pringle invites you to "click") and compliance (clicking), and it may be that conflation of cause and effect is less frequent in commercial web development. However, in the academic literature, as exemplified by the above quote by Witmer and Singer on immersion (Witmer & Singer, 1998), cause and effect are sometimes less clearly delineated.

In 1997 Webster and Ho presented one of the first multiple-question subjective scales attempting to measure audience engagement in multimedia presentations (Webster & Ho 1997). In addition to asking directly whether the participant felt the presentation was engaging, Webster and Ho divided the components of their questionnaire into those that measure "engagement" (the effect) and "influences on engagement" (the causes). In many ways, this division resembles outputs and inputs. However, in a more recent study to validate a new subjective instrument on engagement, this division between inputs and outputs is absent (O'Brien & Toms, 2009). In the O'Brien and Toms study, exploratory factor analysis resulted in six overarching attributes of engagement derived from the questionnaire items: perceived usability, aesthetics, focused attention, felt involvement, novelty, and endurability (where endurability is liking something so much that you recommend it to others in the future). Attention, involvement and endurability are clearly responses derived from the participant that could be considered outputs. However, novelty, aesthetics and perceived usability (efficiency and efficacy of the web site) are problematic as outputs. Although the judgment of what is novel, what are good aesthetics, and what is efficient might vary from person to person, a developer would see all three as controllable inputs and designed

into the development process—certainly web site efficacy (a component of perceived usability) is not something that resides fundamentally in the end-user.

This highlights a more general confusion between inputs to the audience and their outputs. When the word *perceived* is put in front of any input, such as *perceived colourfulness,* what typically would be an input is reclassified into an output. Consider an example in which we are comparing two versions of a digital experience, where version 1 is greyscale and version 2 is in colour; objectively, the greyscale version is not colourful, and its lack of colour is a planned input, and the lack of colour does not require interpretation—greyscale *is* colourless. However, we could administer to experimental participants a scale asking, "How colourful did you find that experience?". We could call the answers to that questionnaire "perceived colourfulness," which would be an output. For the purposes of cause and effect, in this example *colourfulness* (perceived or otherwise) *is a controllable input*; colourfulness is a cause—not an effect derived from the audience. However, the clear relationship between colourfulness and *perceived colourfulness* is useful as a test of fidelity in encoding and decoding: are the computer monitors differentiating colour from greyscale? Are the participants colour-blind? Do the participants speak English and understand the questionnaire?

As is axiomatic in Human Computer Interactions, the ability of inputs to engender planned outputs depends upon having a particular user (i.e. audience) and context (Seffah et al., 2006). While a website may allow for colour-blind end-users, it will be developed with maximum functionality for an audience that sees in colour. Some pre-definition of the audience is especially important for commercial media, as inputs for commercial processes are usually designed to engender specific outputs. Inputs, such as colourful images or graphics, are expected to be applied to a modal audience, which is usually defined in terms of age, language and special interest (which can incorporate gender).

Interpretive Components Defy Prediction

The key distinguishing feature of outputs is that they involve an interpretive component or entry into a biological system. This is as true for measuring

breathing rates as it is for subjective measures of user satisfaction. While individual inputs are controllable and directly maximisable, attempting to maximise an output via maximising individual input channels may not work in a linear fashion—hence the need for experimental assessment of outputs.

Thus, a problem arises with assessment instruments that combine an input with an output (e.g. combining *colourful* with *interesting* into a single output measure). Mixing inputs and outputs will obscure the relationship between cause and effect because the interpretive step will be overridden in part of the instrument. The true causal relationship will be masked, because an assumed causal relationship will be forced into the instrument's measurement of outputs. This problem will create false inferences in cases where the assumed causal relationship does not work. Take the example of colourful text, which should make a web page more interesting than greyscale. Colourful text will not make a web site on Sanskrit grammar theory more satisfying to adolescents than celebrity gossip in black and white.

Outputs will be highly dependent on audience and on context; viewing a web site on a mobile platform, while in a loud environment such as public transport, will affect many outputs, from web site comprehension to basal heart rate. Thus, outputs can be managed, but rarely entirely controlled. Because outputs involve an interpretive component or entry into a biological system, outputs are (usually) less consistent between individuals than inputs. This makes the causal relationship between controllable input factors and desired outputs even more tenuous.

An example from our own lab was the design of a control stimulus that was meant to elicit boredom from all participants, while maintaining their focus and attention. We attempted to minimise all aspects of this stimulus (the input) that might be interesting, hoping the result would be boring—but quite a few participants still found it engaging, but for reasons we did not predict. To minimise any empathy or emotional interest, we selected two minutes of footage showing the production of large pipes (e.g. those carrying municipal sewage). This footage showed no human faces; it focused mostly on the pipes, clay (used to make the pipes) and heavy machinery. To minimise the meaning of the stimulus, we removed the soundtrack, and replaced it with a conversation between two men in Estonian; this should have been incomprehensible, as none of our volunteers in Britain would have studied

Estonian (or any related language). We felt that having no soundtrack might allow viewers to piece together a meaning from what they were watching; we reasoned that accompanying the pipe factory video with a conversation that was unintelligible would serve to confuse and disengage viewers. To minimise any potential interest in the voices themselves, the Estonian conversation was slowed down by 11%, which made the voice tones low and soporific, as well as dragging the conversation's pace.

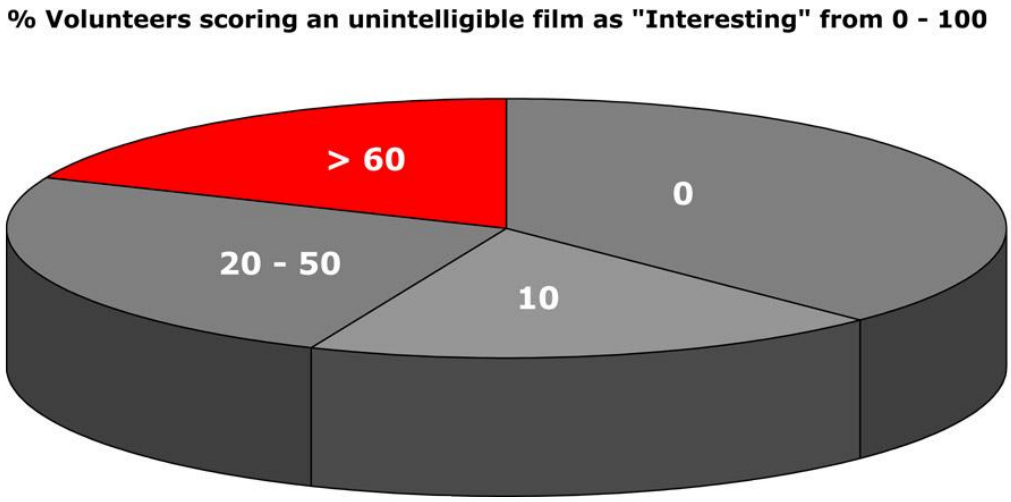

Figure 1

Percentage of volunteers scoring an unintelligible film as "interesting". Each segment of this pie chart represents the percentage of volunteers whose rating (of "I felt interested") is as labelled. The rating scale had descriptive anchors at 0 ("not at all") and 100 ("extremely"). 38% of the volunteers rated the film's interestingness as 0, 18% rated it as 10 out of 100, 25% of volunteers rated it between 20 to 50, and 19% of volunteers rated it 60 or above.

Despite successfully minimising both the audio and visual elements associated with engagement, 1 in 5 experimental participants found this stimulus genuinely interesting. In a rating scale of how interested they felt between 0–100 (where 0 equals "not at all" and 100 equals "extremely"), although more than half of our volunteers rated the stimulus as almost completely uninteresting (as predicted), 19% of our experimental volunteers rated their interest in this stimulus as 60 or above (see Figure 1). In informal discussions at the end of such experiments, the interested participants often mentioned that they were trying to figure out some puzzle, such as why we were showing them this, or what language it might be. This example shows the problem with mixing inputs (such as intelligibility) with outputs (such as

interest) in the same questionnaire. Normally experiences that are unintelligible are less engaging; however, in this experiment an unintelligible stimulus was very interesting to a subset of volunteers. If we had used an engagement questionnaire where participants rated the Estonian pipes film both on how engaging they found it *and* on how intelligible it was, and if we had added up those two scores, the low intelligibility scores would have masked the fact that some participants found this film highly interesting.

To summarise, it is critical that, when assessing the relationship between inputs and outputs, controllable inputs to the end-user must not be conflated with outputs engendered in the end-user. Inputs can be controlled by design, but to make genuine inferences about how audiences respond, unadulterated outputs must be assessed directly; they cannot be viewed as entirely controllable or predictable.

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