Engagement in HCI: Conception, Theory and Measurement

KEVIN DOHERTY and GAVIN DOHERTY, School of Computer Science and Statistics,
Trinity College, Dublin

Engaging users is a priority for designers of products and services of every kind. The need to understand users' experiences has motivated a focus on user engagement across computer science. However, to date, there has been limited review of how Human–Computer Interaction and computer science research interprets and employs the concept. Questions persist concerning its conception, abstraction, and measurement. This article presents a systematic review of engagement spanning a corpus of 351 articles and 102 definitions. We map the current state of engagement research, including the diverse interpretation, theory, and measurement of the concept. We describe the ecology of engagement and strategies for the design of engaging experiences, discuss the value of the concept and its relationship to other terms, and present a set of guidelines and opportunities for future research.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**;

Additional Key Words and Phrases: Engagement, HCI, user experience, theory, measurement, design

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1 INTRODUCTION

Engagement is a major theme of research within Human–Computer Interaction (HCI) and related fields including artificial intelligence, adaptive computing, learning systems, e-government, social networking, behaviour change, and affective computing. However, it is a topic that continues to pose challenges for researchers and designers. What is engagement? What does it mean to be engaged? Which theoretical frameworks support engagement? Can engagement be measured? Can we design for it? In this article, we examine these recurring questions through systematic review.

1.1 Why Review Engagement?

Engagement is a universal goal in the design of content, products, systems, and services. Every designer strives to engage users. The need to understand users and their interactions with technology has motivated a turn towards 'user experience' within HCI and design (McCarthy and Wright 2004). The concept of user engagement has been employed to understand user experience (McCarthy and Wright 2004), motivate students (Fredricks et al. 2004), analyse interaction online (Lehmann et al. 2012; Thomas et al. 2016), guide autonomous systems (Bohus and Horvitz 2009a),

Authors' addresses: K. Doherty and G. Doherty, School of Computer Science and Statistics, Trinity College, Dublin, Dublin 2, Ireland; emails: {dohertkc, Gavin.Doherty}@tcd.ie.

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and to appraise technologies for wellbeing, civil services, social networks, and more (Jung and Lee 2016; Kim and Kleinschmit 2012; Linnemeier et al. 2012; Wiezer et al. 2013).

Many working within these domains have struggled to pin down this nebulous concept, however. Numerous interpretations of engagement have emerged, motivated by the potential of this versatile concept but also limited by conflicting definitions, hidden assumptions, unreliable inference, and imprecise generalisations. To date, analysis of the value of the lens of engagement has been limited, and difficulties understanding and adopting the term persist, a topic of concern for many within the community:

> It is unclear exactly what to measure and how to measure it and what the important measures are for specific scenarios. It is also unclear how different aspects of user engagement relate to each other. (Attfield et al. 2011)

> The multidimensional nature of user engagement makes it challenging to measure. While we are very comfortable measuring concrete events, such as the number of errors a user makes when interacting with a system or how long it takes to find the answer to a factual search query, we are less firmly seated when it comes to activities for which there are no visible or physical outcomes. (O'Brien and Toms 2013)

1.2 Review Synopsis

This article provides a grounding for researchers and designers by mapping the current state of engagement research. Section 2 describes the review methodology. Section 3 examines the diverse interpretation of engagement across the literature, including explicit definitions of the term and the range of theory brought to bear on the concept. Section 4 positions interpretations of engagement in terms of state, agent, and interactional framings within an HCI ecology. Section 5 describes the variety of approaches to measurement for the purposes of understanding, designing, and implementing engagement. Section 6 distinguishes strategies for the design of engaging user experiences employed across the literature. Finally, Section 7 discusses the value of the concept of engagement, opportunities for future research, divergent domains of knowledge, and guidelines for those working with the concept before presenting conclusions.

2 REVIEW METHODOLOGY

2.1 Data Collection

This article presents, to the best of our knowledge, the first systematic review of engagement across computer science. This review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see Figure 1) (Kitchenham et al. 2009; Moher et al. 2009). Adopting minimal exclusion criteria enabled a significant and representative corpus with which to consider the question;

> **How is the concept of engagement interpreted, understood, and measured across the HCI and computer science literature?**

The review corpus was sourced, during the month of May 2014, from the Association for Computing Machinery (ACM) Guide to Computing Literature, the single largest source of computer science literature, containing just short of 2.5 million papers. A search for works that included the term 'engagement' in either title or keyword produced 1,150 results (see Figure 1). These 1,150 papers were then parsed by a single reviewer to exclude papers outside the remit of the review. Papers were rejected during the initial screening if they

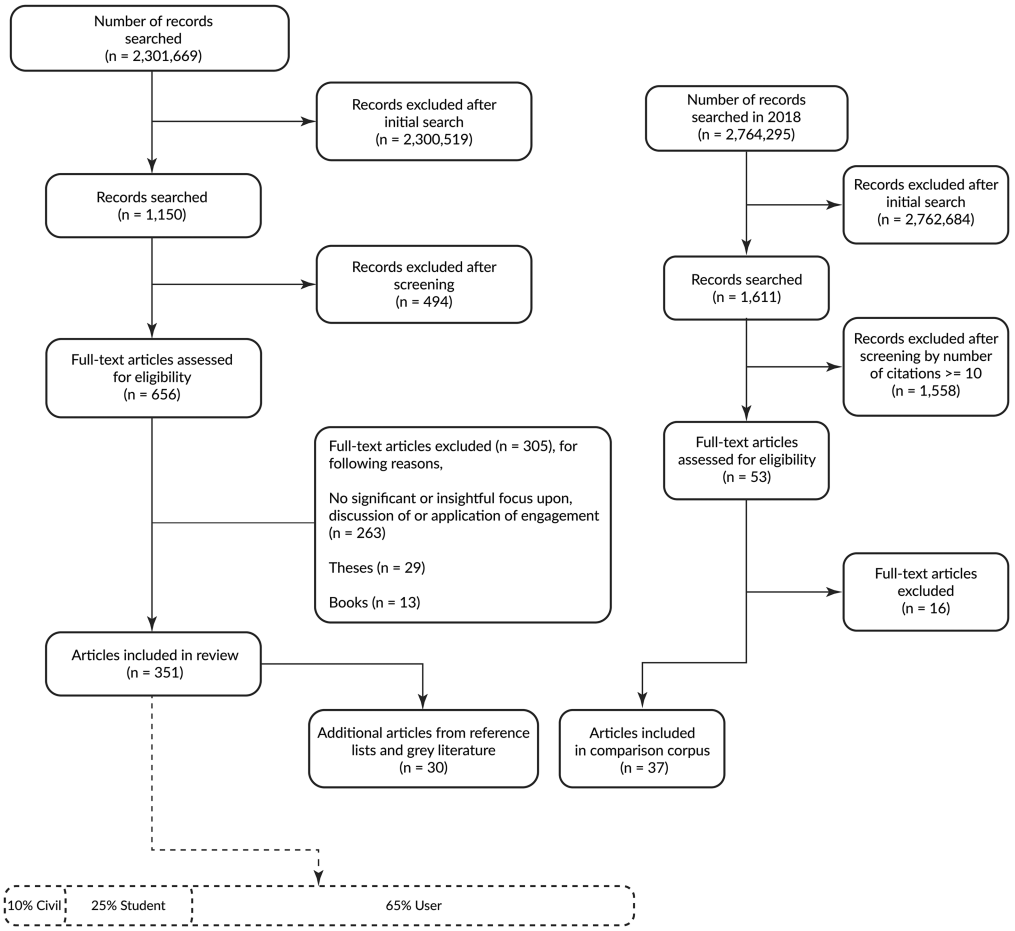

Fig. 1. Review process diagram.

(1) did not focus on the use of digital technology

and during a second full-text assessment of eligibility if they

(1) provided no significant or insightful focus on, discussion of, or application of the concept of engagement,
(2) took the form of dissertations,
(3) took the form of authored books.

No additional criteria, such as date or source constraints, were set. Examples of papers excluded in this phase were those focused on automatic transmission engagement in automobiles, civic engagement with public policy without the mediation of a computer system or studies of engagement with the Science, Technology, Engineering and Mathematics (STEM) domain. This process resulted in a final tally of 351 papers. Three categories of research could be immediately discerned, relating to user, student, and civil (or public) engagement (see Figure 1).

The scale of this review meant that it took several years to finalise. To ensure the continued relevance of our findings, and identify any recent trends, an update was carried out in January

2018 prior to publication. A repeated search using the original criteria for the intervening period produced a corpus of 1,611 publications. Publications with 10 or more citations were subjected to analysis. Of these 53 papers, 37 met the original review criteria. This sample demonstrated many of the patterns of the original corpus. See Section 7.5 for discussion of this updated sample.

2.2 Analysis

During the review process, a spreadsheet was used to log pertinent features of each paper, ensuring consistency and replicability. This log structure incorporates coding dimensions derived from the aims of the review, initial assessment of the engagement literature and the research methods literature (Fink 2013; Grix 2010; Hart 2001) as well as the PRISMA guidelines (Moher et al. 2009);

- Administrative Coding (title, author(s), date published, publication type and title, key words)
- Engagement Coding (definition, theories, attribute or process construal, number of states, engagement focus, social emphasis, passive or active, negative perspectives, application context, users targeted, platform, measures applied, engagement synonyms)
- Methods and Study Quality Coding (sample size, sample demographics, experimental design, sampling procedure, statistical techniques, nature of the reported data, study aims, originality, study description, reviewer notes)

This coding scheme informed a thematic analysis of the final corpus, leading to a detailed mapping of the landscape of engagement research. As expected, interpretation of engagement is highly diverse. The publication of engagement research is increasing exponentially at a rate of approximately 28% per year. While this trend likely coincides with an increase in user experience research, it illustrates the growing body of scholarship on this topic.

3 WHAT IS ENGAGEMENT?

The need to understand users and their interaction with technology motivated a turn towards user experience within HCI (McCarthy and Wright 2004). This was followed by a turn towards engagement (Bardzell et al. 2008). McCarthy and Wright write that understanding user experience is a task complicated by our own immersion in experience and an assumption of consistent interpretation (McCarthy and Wright 2004). Engagement is also a feature of our day-to-day language.

3.1 Definitions of Engagement

In approaching a definition of engagement, the papers of this corpus draw on a diverse literature, including the origins of the concept in social and cognitive psychology, while also offering new conceptions. One hundred and two definitions of engagement were encountered across the 351 papers of this corpus. By explicit definitions, we refer to statements of the form "Engagement is . . . ," or similar. Several conceptions were cited on multiple occasions, the single most-cited being that of Sidner et al., encountered on six occasions:

> By engagement, we mean the *process* by which two (or more) participants establish, maintain and end their perceived *connection*. This process includes: initial contact, negotiating a collaboration, checking that other is still taking part in the interaction, evaluating whether to stay involved, and deciding when to end the connection. (Sidner et al. 2004) (emphasis added)

This definition positions engagement as a component of social connection. Any explicit definition constitutes certain assumptions on the part of the author. Sidner et al., in this instance, explicitly cast engagement as a *process* composed of three distinct phases, a beginning, a period

of sustention, and an end. These phases are then further divided into a series of *user actions*. This framing implicitly places the definition within the context of a conversation between at least two agents, where the user is cast as an *active* and *receptive* participant and engagement as a continuous, *synchronous* process with a clearly defined beginning and end. Established from the *user's perspective* and distinguishing *discrete components* of interaction, this definition lends itself to the development of autonomous and task-focused systems rather than to a single user's engagement with a screen-based interface for example.

Quesenbury links engagement to the qualities of an interface:

> the *degree* to which the *tone* and *style* of the interface makes the product pleasant or satisfying to use. (Quesenbury 2002) (emphasis added)

O'Brien and Toms describe engagement as a quality of user experience with multiple component features:

> Engagement is a *quality* of user experiences with technology that is characterized by *challenge*, *aesthetic* and *sensory* appeal, *feedback*, *novelty*, *interactivity*, perceived *control* and *time*, *awareness*, *motivation*, *interest*, and *affect*. (O'Brien and Toms 2008) (emphasis added)

Zyngier divides student engagement into behavioural, emotional, and cognitive components:

> Student engagement is a *mix of several components* 1) *Behavioural*: persistence and participation, 2) *Emotional*: interest, value and valence, and 3) *Cognitive*: motivation, effort and strategy. (Zyngier 2008) (emphasis added)

Douglas and Hargadon supply a definition of engagement with a distinct hedonic inclination, tied to the concepts of immersion, narrative flow and schema theory:

> The pleasures of *immersion* stem from our being completely absorbed within the ebb and flow of a familiar narrative schema. The pleasures of engagement tend to come from our ability to recognize a work's overturning or conjoining conflicting schemas from a perspective outside the text, our perspective removed from any single schema. (Douglas and Hargadon 2000) (emphasis added)

Dobrian et al. describe engagement as a proxy for involvement and interaction:

> Qualitatively, engagement is a *reflection* of user *involvement* and *interaction*. (Dobrian et al. 2013) (emphasis added)

Jaimes et al. define engagement in the context of social media, employing the language of captivation and motivation:

> Engagement defines the phenomena of being *captivated* and *motivated*: engagement can be measured in terms of a single interactive session or of a more long-term relationship with the social platform across multiple interactions. Thus, social media engagement is not just about how a single interaction unfolds, but about how and why people develop a *relationship* with a platform or service and integrate it into their lives. (Jaimes et al. 2011a) (emphasis added)

Laurel ties engagement directly to an emotional state:

Table 1. Technologies with Respect to Which Engagement Has Been Studied

Technology	Mentions
Online	76
Personal Computers	74
Mobile Devices	30
Robotics	22
Public Displays	17
Intelligent Virtual Agents	15
Sensors	14
Gaming Systems	8
Virtual Reality	8
Kiosks	6
Other	38
NA	59

> Engagement refers to the (emotional) *state of mind* the user must attain to enjoy the representation, that is, a willing *suspension of disbelief*. (Laurel 1991) (emphasis added)

Context Specific Definitions. This brief synopsis highlights the diverse language brought to bear on the topic of engagement and the importance of context in evaluating any definition. Technology itself is an important element of context, and engagement has been examined with respect to a diverse range of technologies (see Table 1). As motivations for, and the value of, particular definitions can vary by context, one approach to defining this highly versatile concept is to reduce its scope. A number of authors have chosen to do so by applying an appropriate prefix. Chilukuri and Indurkhya describe *narrative engagement*, a concept comprising narrative understanding, attentional focus, emotional engagement, and narrative presence (Chilukuri and Indurkhya 2011). Churchill writes "how about 'vongagement'—for voluntary engagement? Or 'invitagement' for invited engagement? Or 'partagement' for participatory engagement?" (Churchill 2010). These distinctions are often key to the value of engagement as a concept.

However, 65% of publications that address engagement do not provide a definition. This likely contributes to the persistent ambiguity surrounding the term. To more fully understand this diversity of interpretation, we turn to the theoretical foundations of engagement.

3.2 Engagement Theory

In striving to understand engagement, researchers have looked to, and developed, a broad range of theory. This sample of the literature contained 372 theoretical frameworks (see Table 2), nets cast to 'rationalize' and 'explain' human–computer interaction (Popper 1959). Some frameworks focus primarily on engagement (O'Brien and Toms 2010b). Others on related concepts such as immersion (Carrigy et al. 2010) and involvement (Webster and Ahuja 2006).

Levels of Theory. Discerning categories of engagement theory allows us to identify approaches to, and motivations, for the interpretation of the concept. Theories are often described as focused on micro (actor-focused) or macro (structure-focused) processes. Flow theory (Cowley et al. 2008), social presence theory (Choi et al. 2014), and cognitive load theory (Oviatt et al. 2008), among others, primarily possess a **micro** focus. These theories tend to construe engagement in terms of the nature and distribution of conscious focus. This facilitates the analysis of individual episodes of interaction and the inference of engagement as a state of experience.

Table 2. Theories of Engagement

Theory	Mentions
Flow Theory	50
Motivation Theory	16
O'Brien and Tom's Model of Engagement	13
Sidner et al.'s Model of Engagement	9
Presence Theory	9
Play Theory	7
Self Determination Theory	6
Independent Television Commission Sense of Presence Inventory	6
ITiCSE Engagement Taxonomy	6
Technology Acceptance Model	5
Social Presence Theory	5
Immersion Theory	5
Activity Theory	4
Involvement Theory	4
Cognitive Load Theory	4
User Engagement Scale	3
Brown and Cairn's Model of Engagement	3
Media Equation Theory	3
Peter et al's Model of Engagement	3
Game Engagement Questionnaire	3
Active Learning Theory	3
Social Capital Theory	3
Richness Theory	2
Engagement Sampling Questionnaire	2
Immersive Tendencies Questionnaire	2
Michalowski et al.'s Model of Engagement	2
Kendon's F-Formation Theory	2
Ermi and Mayra's Model of Immersion	2
etc.	.

Flow theory is a prominent example of this perspective (Seah and Cairns 2008; Webster and Ahuja 2006). This theory posits the existence of a state of optimal and enjoyable experience characterised by a tractable challenge, immersion, control, freedom, clarity, immediate feedback, temporal insensitivity, and changes in one's sense of identity (Cowley et al. 2008). This framework provides a means of measuring flow, often employed as a synonym for engagement, through its component parts, as well as a target for would-be interaction designers, the flow state. One model of game experience adopted this state as the utility for the player (Cowley et al. 2008). This factored model presents engagement (flow) as demarcated and attainable through a balance of factors including challenge and skill.

In contrast, theories of motivation (Seddon et al. 2008), self-determination theory (Wiebe et al. 2014), and narrative theories (Douglas and Hargadon 2000) can be described as **macro** in nature. These frameworks tend to support higher-level analysis, reflecting aggregate, socio-structural, and temporal factors. Schema theory has been employed in the analysis of flow, engagement, and immersion in traditional and interactive narratives, for example (Douglas and Hargadon 2000). Macro perspectives feature in reflection on the use of mobile media technologies (Lai 2014), ethnographic

analysis of users' *environmental engagement* through in-car GPS systems (Leshed et al. 2008), and in Borgmann's critique of the pattern of modern life as "one of disengagement, in which technological devices might relieve us of tedious effort but do so at the expense of our engagement with the world" (Dindler et al. 2011; Leshed et al. 2008).

Cognitive, Emotional, and Behavioural Engagement. Is engagement cognitive, emotional, or behavioural? Several authors make these distinctions (Zyngier 2008; Bouta and Retalis 2013; Islas Sedano et al. 2013).

Interpretations of engagement as **cognitive** in nature often focus on conscious components such as effort (Islas Sedano et al. 2013; Sun 2014), energy (Birnholtz et al. 2013), awareness, and attention (Islas Sedano et al. 2013). This interpretation renders engagement more easily quantified and is often accompanied by a focus on process and strategy (Bouta and Retalis 2013; Islas Sedano et al. 2013), as is the case with Fredricks et al.'s *cognitive engagement scale* that denotes "an individual's voluntary efforts to understand and master challenging tasks" (see Sun (2014)).

Engagement has also been described as "primarily understood as an emotion" (Laurel 1991). Definitions of **emotional** or affective engagement tend to emphasise the subjective nature of experience, encompassing identification, belonging, values, attitudes, and emotions (Islas Sedano et al. 2013), reflected through expressions of interest, boredom, achievement orientation, values, and feelings (Bouta and Retalis 2013). Interpreting engagement in these terms supports the adoption of theories of emotion, of which there are many. One such interpretation describes engagement as a state of high valence and arousal on the circumplex model of emotion (Latulipe et al. 2011). Another locates engagement between boredom and stress "within a framework of arousal states" (Churchill 2010).

A **behavioural** construal of engagement emphasises action and participation, promising more objective measurement (Asteriadis et al. 2009; Bouta and Retalis 2013; Islas Sedano et al. 2013). Bianchi-Berthouze et al. express the belief that the cognitive focus of many theories of engagement neglects the physical component (Bianchi-Berthouze et al. 2007). Studies of gameplay using the GuitarHero controller revealed a correlation between player engagement and physical movement. Movement appeared "not only to increase the players' level of engagement but also to modify the way they get engaged" (Bianchi-Berthouze et al. 2007).

Conceptions of engagement can be divided along many lines, "academic, cognitive, intellectual, institutional, emotional, behavioural, social, and psychological" (Ting et al. 2013). These distinctions are not based on objective knowledge of engagement as a universal neurophysiological or social phenomenon but are made to facilitate a particular form of context-dependent analysis and design. These motivations reveal the ontological perspectives brought to bear on engagement.

Trait, State, or Process. A key distinction among definitions of engagement is its interpretation as a trait, state, or process. These characterisations are almost always made implicitly and so merit closer examination.

Engagement can be interpreted as **trait** based; a stable characteristic of *persons* or *systems*, a propensity to engage or be engaged. *Cognitive absorption* is one example of this interpretation, described as a user's "propensity to become absorbed in the activities around using a computer" in contrast to *immersion*, construed as a comparatively dynamic state (Seah and Cairns 2008). *Within-person process* and *individual-difference structural* theories of cognition have long been the subject of debate in personality psychology (Fleeson 2007). However, the role of personality with respect to engagement featured only rarely within this corpus (Bixler and D'Mello 2013; Cowley et al. 2008; Goldberg et al. 2011). Improved knowledge of individual patterns of engagement might support personalised, engaging experiences (Barco et al. 2014).

Engagement is most frequently characterised as a variable **state**, ascribed to the *user* (O'Brien and Toms 2008), a *system* (Bohus and Horvitz 2009c), or to *interaction* itself (Deray and Simoff

2012). These conceptions tend to emphasise perception, reflection, and a responsive, dyadic form of interaction. One of the features of a discrete variable is the number of states it can adopt. The design of Pêle-Mêle, a multi-party video communications system, explored this choice with respect to engagement (Gueddana and Roussel 2006). The system's state of engagement is determined by the user's presence, motion, and distance. The view that systems should be designed to support variable degrees of engagement, and smooth transitions between these, merits wider adoption. Casting engagement as a dynamic state, whether discrete or continuous, is a reductive stance. This perspective facilitates measurement and modelling and also presents engagement as a finite resource, a form of conscious currency to be managed by human and machine in interaction.

While characterising engagement as a dynamic state suggests a process of change, explicit consideration is given in the literature concerning its function as a **process** (O'Brien and Toms 2008). However, the processual nature of engagement is often lost in its operationalisation as a more easily measured discrete state. Very often, related concepts such as motivation are instead used in discussion of issues relating to the process of user engagement and disengagement (see Section 5.3). Description of engagement as a process enables the analysis of change over time and between interactions. One hybrid view of engagement describes a *process of transition* between different *modes* from physical to contemplative engagement (Dindler et al. 2011).

4 THE ECOLOGY OF ENGAGEMENT

Advancement of engagement research requires an understanding of appropriate distinctions among perspectives. In addition to examining the theoretical frameworks employed by researchers, we propose turning to the ontological framing of engagement, expressions of which are rarely explicit. We locate conceptions of engagement within the framework of an HCI ecology (Jung et al. 2008; Raptis et al. 2014) composed of state, user, and interaction.

4.1 The Engaged State

Engagement is often positioned at the level of individual conscious experience, whether described as a **state** (Laurel 1991) (Chen et al. 2011; Goldberg et al. 2011; Houtkamp et al. 2012; Sundar et al. 2012) or a perceived **quality** of experience (Baeza-Yates and Lalmas 2012; Lehmann et al. 2012; McCay-Peet et al. 2012; O'Brien and Toms 2013). These characterisations are subject to degrees of abstraction. State-based interpretations of engagement range from highly reductive transactional conceptions (Gueddana and Roussel 2006) to complex representations of subjective experience (Sundar et al. 2012). A rationalist epistemology is often apparent in descriptions of engagement states as representations of affect, cognition, or conation (behaviour) (Bouta and Retalis 2013; Zyngier 2008; Islas Sedano et al. 2013).

Engagement is also, and often simultaneously, described as a qualitative **character** of perceived experience (Corrigan et al. 2013; Kim et al. 2013; Marsh et al. 2008). This is a phenomenological framing, comprising interpretation of engagement as a distinct shade of conscious experience. Such instances of subjective sensation have been described as 'qualia' (latin: meaning 'of what kind') (Dennett 1988). These states are 'intentional,' in the sense that they are 'about something' (Dennett 1971). Definitions of engagement often embody an 'object,' a focus, an intentionality.

4.2 The Engaged Agent

Engagement is also understood at the level of users and systems (Castellano et al. 2009; Poggi 2007; Dow 2007; Hwang and Thorn 1999; Schoenau-Fog 2011; Webster and Ahuja 2006). When we talk about engagement in these terms, we do not refer to action alone or a state in isolation but often invoke valence, desire, commitment, intent, participation, volition, attention, immersion, and motivation.

Understanding the Engaged User. Attempts to define the engaged user may consider predispositions, expectations, motivations, mood, age, gender, and so on. One student may disengage "because he genuinely finds the work too easy," another "may be capable of doing the work but lacks confidence and feels too anxious about failure," and another "may not have the required skills but is wary" of using a system designed to help "because she has learned not to expect useful assistance from peers, parents or even teachers" (Beal et al. 2006). Attempts to model systems and users are often encountered in learning systems research (Kucirkova et al. 2014; Naps et al. 2002; Tootell et al. 2013). One study divided participants into 'highly sensitive' and 'less sensitive' groups based on a personality difference known as *electrodermal lability*. Participants in the 'highly sensitive' group engaged least with strongly expressive agents and most with softly expressive ones (Choi et al. 2012).

Motivation. Characterisations of engaged agents often refer to related concepts such as motivation, that themselves are abstractions of self and experience (Cocea and Weibelzahl 2007; Kim et al. 2013; Liu et al. 2011; O'Brien and Toms 2010b; Tashiro and Dunlap 2007). Motivation has been defined as a dynamic process in which sustained effort is applied to pursue goals that satisfy needs "subject to cognitive processes and set against values" (Seddon et al. 2008). Motivational factors are believed to include reasons for action (needs and values), interest, a conducive social context, effective feedback, and a sense of agency arising from choice, control, and an expectancy of success (self-efficacy and self-worth) (Seddon et al. 2008). The process of engagement has also been described as a 'feedback loop' in which experience with a task shapes "the more state-like elements of self-efficacy and motivation that in turn influences the user's desire to re-engage with a task" (Wiebe et al. 2014). The Mobile User Engagement Model (MoEn) associates engagement with *functional* (efficiency, ease of use, saving time), *hedonic* (fun, enjoyment, pleasure), and *social motivations* (desire to connect and share with others) (Kim et al. 2013).

4.3 Engaged Interaction

Engagement has also been positioned as a feature of interaction itself rather than a character of states or agents (Davies 2002; Deray and Simoff 2012; Dobrian et al. 2013; Sidner et al. 2005). Interaction can refer to actions and relationships among states, agents and objects at specific moments or over time. Within the engagement literature, interaction is often employed as a direct proxy for engagement, marrying engagement to a scale of use, the unit of which is interaction. This is a measure of quantity not quality. Other interpretations match degrees of engagement to forms of interaction. Mallon and Webb's framework for engagement in narrative multimedia describes interaction as a dimension of engagement that incorporates skill-based interaction, the relevance of dialogue and causality, the illusion of intelligence, and invisibility of the medium (see Schuurink et al. (2008)). Interaction has also been described as "an essentially reactive activity" in contrast to engagement which "has an affective component" (Turner 2010). While engagement has been viewed as a product of interaction (Deray and Simoff 2012; O'Brien and Toms 2008; Sundar et al. 2012), it has also been thought so broad a notion that it is "most productive to consider engagement as a perspective on interaction, rather than a clearly defined entity" (Dalsgaard et al. 2011).

An HCI ecology provides a scaffolding for conceptions of engaged states, experiences, selves, and interactions, whose distinction is often implicit within the literature. The measurement of engagement further reflects these themes.

5 MEASURING ENGAGEMENT

The variety of methods applied to the measurement of engagement speaks to the versatility of the concept (see Table 3). Subjectivity-oriented measures tend to target the perceptual and experiential nature of the concept. Objectivity-oriented measures entail a reductive interpretation, often in the

Table 3. Measures of Engagement

Measure	Applications
Questionnaire	124
Behaviour Logging	69
Observation	44
Task Outcomes	26
Interview	23
Eye Tracking	19
Discussion	10
Electroencephalogram (EEG)	10
Audio Signal Analysis	8
Galvanic Skin Response (GSR)	8
Facial Analysis	7
Review	6
Head Pose	5
Physical Motion Tracking	5
Body Pose	4
Presence Detection	3
Electrocardiogram (ECG)	2
Heart Rate	2
fEMG	1
Gesture Tracking	1
Heat Flux	1
Pen Pressure	1
Pupil Diameter	1
Systolic Blood Pressure (SBP)	1
Supraorbital Thermal Imaging	1
Temperature Monitoring	1
No Engagement Measure	106

search for actionable data. The literature features many examples of both approaches to measurement including questionnaires, interviews, measures of outcomes, and digital behaviour logging.

5.1 Subjectivity-Oriented Approaches

Subjectivity-oriented measures include observation, questionnaires, interviews, and other forms of self-report. As with any methodology, the choice of these methods entails compromise. These approaches support rich description coloured by subjectivity, cognition, emotion, and memory.

Questionnaire Methods. Questionnaires are the most frequently applied measure of engagement (see Table 3). They are easily applied and can support detailed analysis (Brockmyer et al. 2009; O'Brien and Toms 2010b; Rozendaal et al. 2008; Seok and DaCosta 2012; Webster and Ahuja 2006). However, they are often retrospective in nature and yield a personally motivated and reconstructed perspective (Latulipe et al. 2011).

The development of the User Engagement Scale (UES) is one of the most thorough attempts to develop an understanding of user engagement within the literature (O'Brien and Toms 2010b). This questionnaire was informed by an initial conceptual framework for user engagement based on analysis of interviews held with 17 participants concerning their experiences with online shopping, searching, video games, and distance learning (O'Brien and Toms 2008). This framework

describes engagement as a process comprised of four stages; a point of engagement, a period of sustained engagement, disengagement and re-engagement, with respect to a system that is "effective, efficient and satisfying." The UES was further informed by a literature review, engagement described thereafter as:

> both a process and product (Kappelman, 1995) of interaction; its intensity may change over the course of an interaction (Said, 2004) depending on the combination of users' needs, goals, emotions, actions, and thoughts, or the format (Chapman, 1997; Jacques, 1996), visual presentation, and organization of the computer interface (Quesenbury 2003). (O'Brien and Toms 2010b)

An initial evaluation study, comprising the responses of 440 participants regarding an online shopping experience, led to the reduction of the scale to 33 items distributed across six principal factors: Focused Attention, Perceived Usability, Aesthetics, Endurability, Novelty, and Felt Involvement (O'Brien and Toms 2010b). A second study, in which 802 participants completed the revised scale with respect to an online book purchase, identified relationships among these factors. It was found that aesthetics predicted perceived usability, focused attention predicted felt involvement and felt involvement predicted endurability. Subsequent analyses led to further refinements of this model (O'Brien and Toms 2010a, 2013; Wiebe et al. 2014).

Experience Sampling Methods. Experience Sampling Methods (ESM) can capture changes in engagement through the repeated report of experience in the moment. These methods are particularly relevant to interpretations of engagement based around flow. The Engagement Sampling Questionnaire (ESQ) (Schoenau-Fog 2011) contains demographic, pre-experience and in-experience components, focused on user objectives, activities, accomplishment, and affect. Questions posed in-experience include a Likert-scale measure of continuation desire and a number of open questions. The ESQ has been applied as part of an iterative game design process (Schoenau-Fog et al. 2012) and in the development of the experiential game Aporia (Bevensee et al. 2012). An ESM approach was also employed to understand users' engagement with an SMS-based pervasive mobile game (Fischer and Benford 2009). These measures construe engagement as a momentary concept, a feature of immediate experience, in contrast to retrospective questionnaires, for example, which often imply a reflective, multifaceted interpretation (Doherty and Doherty 2018).

Observational Methods. A variety of methods have been employed to capture and describe the subjective experience of engagement. An *ethnographic* approach informed the development of a five-phase model of user engagement with public displays, comprising receptiveness, interest, evaluation, engagement, and disengagement (Glasnapp and Brdiczka 2009). *Qualitative analysis* identified immediate conversation, creative production, and reflective observation as dimensions of engagement with research videos (Caglio and Buur 2012).

Inferring Engagement from 'Subjective' Data. An important distinction among subjective measures is the degree to which prior assumptions bias the inference of engagement. Questionnaires, for example, often invite closed-ended responses and are therefore deductive rather than inductive. These choices are highlighted in the creation of engagement scales (Brockmyer et al. 2009; O'Brien and Toms 2010b; Rozendaal et al. 2008; Seok and DaCosta 2012; Webster and Ahuja 2006). The Game Engagement Questionnaire (GEQ), for example, interprets engagement as a "generic indicator of game involvement" incorporating immersion, presence, flow, psychological absorption, and dissociation (Brockmyer et al. 2009). While the User Engagement Scale (UES) measures focused attention, perceived usability, aesthetics, endurability, novelty, and felt involvement (O'Brien and Toms 2010b).

Measures of engagement are context-dependent. O'Brien and Toms, for example, state that the User Engagement Scale (UES) "incorporated effectiveness and satisfaction, but not efficiency. This

makes sense since an engaged user may not be concerned about how much time they are spending" but it means that "some usability metrics, including time spent performing a task or examining a screen, may not be applicable" (O'Brien and Toms 2010b). Face validity can also indicate whether the questions posed by a particular scale relate coherently to the context of measurement. A scale developed by Konijn and Hoorn to measure *involvement*, for example, asks whether a figure "is appealing" and "makes me happy," a highly context-dependent interpretation (van Vugt et al. 2007).

Open-ended methods can support an exploratory approach although lack the reliability and ease of application provided by questionnaires. Interviews can reveal "indications of engagement" for example, "reported as 'awareness,' 'involvement,' 'immersion' and so forth." Instead of asking "were you engaged?," participants can be asked to describe their experience (Swift et al. 2010).

5.2 Objectivity-Oriented Approaches

Objectivity-oriented measures attempt to infer engagement without recourse to direct questioning or human involvement. This includes such techniques as logging behaviour and interaction, psychophysiological measures, and audio and visual analysis. The advantage of these approaches lies in their ease of application, limited disruption of experience, and reduced user burden. We describe these measures as oriented towards objectivity, given their approximation of engagement through its observable features. However, all such measures are themselves imbued with a certain subjectivity, introduced through users' awareness of observation and researchers' experimental and interpretive choices.

Behavioural Trace Measures. The choice of engagement measure has been described as a tradeoff between the *scale of data capture* and the *depth of understanding* (Baeza-Yates and Lalmas 2012). The simplest of measures adopt single variables as proxies of engagement, such as the number of mouse clicks on a web-page. These measures are often employed when access to users is limited, as in the case of e-publications (Lee et al. 2009), email spam exposure (Dasgupta et al. 2012), blog visitor engagement (Hennig et al. 2013), online networked user engagement (Lehmann et al. 2013a), online multitasking (Lehmann et al. 2013b), search engine engagement (Song et al. 2013) and analysis of the effects of links on networked user engagement (Yom-Tov et al. 2012), the impact of video quality (Dobrian et al. 2013), and online engagement as absence time (Dupret and Lalmas 2013).

Behaviour logging approaches support the assessment of engagement at significant scales. Lehmann et al. collected data from two million users across 80 websites, according to three categories of engagement metrics: popularity, activity, and loyalty (Lehmann et al. 2012). These data allowed the authors to define five user types based on the number of days that included a visit to a site, to calculate the proportion of each user group per site and to cluster sites with similar user groups, extricating patterns of engagement (Lehmann et al. 2012).

Psychophysiological Measures. Another broad category of measures which has been used to infer engagement are *psychophysiological.* Electrocardiography (ECG), heat flux (HF), and electroencephalography (EEG) measures have all been employed as proxies for engagement (Belle et al. 2011). Features of the signals produced by these methods enabled a binary classification of engagement trained on data captured while eight subjects viewed two 20-minute sets of 3- to 5-minute-long video clips, one set deemed engaging, the other not (Belle et al. 2011). This model achieved greater than 90% accuracy, precision, and recall. EEG measures have also been used to infer music engagement without interrupting the listening experience (Blankertz et al. 2010). Predictive models, based on EEG and motion-tracking data, achieved 67% engagement classification accuracy across-subjects and 85% accuracy within-subjects.

Attempts have also been made to infer engagement from audio and video data. Ishii and Nakano measured conversational engagement between a user and a Wizard-of-Oz–controlled virtual agent in the role of a mobile phone salesperson by examining eye-tracking data, speech transcriptions,

the virtual agent's gaze, and gestures as well as observed and user-reported judgements of user-attitude (Ishii and Nakano 2008). Analysis of these data revealed that engaged users behaved more cooperatively, redirecting their attention to a focused object when referred to by the agent (Ishii and Nakano 2010). Further research, incorporating *head pose* and *topic change* information, led to the development of a binary classification of engagement with an accuracy rate of 77.8% (using 10-fold cross validation) and a three-class model with an accuracy rate of 88.75% (Ooko et al. 2011). Proponents of these approaches have reported promising results. However, many studies have taken place in laboratory environs, narrow contexts of use and with small numbers of users (Bixler and D'Mello 2013; Cai and Lin 2012; Foster et al. 2013; Sanghvi et al. 2011; Xu et al. 2013), and so it is difficult to generalise initial findings.

Inferring Engagement from 'Objective' Data. Data from 'objective' sources offers several advantages. It can be captured at large scales without human involvement, has the potential to be gathered in an ambulatory fashion, and supports the action of autonomous systems. Reductive data can also lead to shallow interpretation, however, such as false attribution of causality, misleading timescale responsivity, and invalid generalisation. If a user spends a long time on a web-page, are they engaged or simply confused? (Birkett et al. 2011) Time spent searching for information can be "involving, but not in a pleasant way . . . just inefficient and frustrating" (Colbert and Boodoo 2011).

Measures are not always as 'objective' as we may assume. The ground truth against which these methods are evaluated is often derived by self-report, annotation, or expert ratings (Bonin et al. 2012; Sanghvi et al. 2011; Xu et al. 2013). Annotated gameplay video was employed as the ground truth for computer-vision-based models of affective posture and body motion in a study of engagement during chess games between children and the iCat robot (Sanghvi et al. 2011). When asked, annotators revealed, perhaps counter-intuitively, that they had associated less movement and an upright or backward leaning posture with higher levels of engagement and patterns of continuous movement and a forward leaning posture with lower levels of engagement. Another group of researchers, organising the annotation of individual and group engagement within a video corpus, imposed no constraints on observers, no timescales for annotation, and no definition of engagement (Bonin et al. 2012). When annotators were asked to describe their process, they stated that they concentrated mainly on "whether the subjects were speaking or not and on the body pose" to determine an individual's level of engagement (Bonin et al. 2012).

The perceptual and experiential nature of engagement is an important consideration in its measurement, regardless of method. We possess *agency* with respect to *affective display*, or perhaps more appropriately in this case *engagement display*. Although "an entity may have an interest in something, this is to be differentiated from the action of showing interest in it" (Peters et al. 2009). This is of particular importance when it is likely for participants to control their display of engagement, due to *social facilitation, inhibition, or loafing* effects, for example (Liu et al. 2011).

While the act of observation alone can influence the display of engagement, many methods also interrupt experience (LeeTiernan and Grudin 2003). A distinction between *implicit*, "non-intrusive, pervasive and embedded," and *explicit* measures is valuable in this respect (Corrigan et al. 2014). One study of human–robot interaction employed a questionnaire every minute in addition to measuring the repetition of errors and the speed at which users diverted their gaze to the robot and interface (Corrigan et al. 2014).

5.3 Motivations for Adoption

The conception and measurement of engagement is interlinked and contingent on the motives of designers and researchers. From this corpus, we discern three key motivations for the adoption of engagement as follows:

(1) **Basic Research** Understanding Engagement
(2) **Design Practice** Designing Engagement
(3) **Systems Development** Implementing Engagement

The first category comprises research focused on the development of generalised theories and models of engagement, often embodying psychological and social factors. This work goes beyond engagement with a particular designed object or process, studying its universal relevance. Examples include extensive models of user engagement (O'Brien and Toms 2008), socio-technological critique (McCarthy and Wright 2004; Leshed et al. 2008), and sociological analysis (Goffman et al. 1978).

The adoption of engagement has also been motivated by design practice. Engagement has been employed as a lens through which to analyse user experience with technology probes and as a concept in the design of user experiences. Patterns of engagement have been used to provide actionable insight into the design of technologies such as mobile games (Fischer and Benford 2009), learning systems (LeeTiernan and Grudin 2003), and websites (Colbert and Boodoo 2011).

A third motivation rests on the capacity of engagement to mediate human behaviour and communication. Developers of autonomous systems have leveraged the role of engagement in interaction, approaching the concept with an eye to synthesis, not just analysis. This approach entails operationalising (translation from conception to signal), modelling (representation within a logical framework), and connecting measures of engagement to appropriate autonomous actions, as in research concerning cognitive assistance during driving (Cai and Lin 2012), the behaviour of a robot bartender (Foster et al. 2013), keystroke analysis during essay writing (Bixler and D'Mello 2013), attention to on-screen information (Asteriadis et al. 2009), and conversational agents (Nakano and Yamaoka 2009; Xu et al. 2013).

5.4 Conclusion

In most cases, an understanding of engagement is best approached through the combination of subjective and objective measures (LeeTiernan and Grudin 2003; Stiubiener et al. 2012). The choice of methodology will depend on the research and design questions being asked (based on the motivation as discussed above), the context and ultimate goals of the system, the interpretation of engagement we choose in service of these, and the need for methodological validity and reliability.

6 DESIGN STRATEGIES FOR ENGAGEMENT

The context of engagement research is broad (see Table 4). In this section, we outline strategies for the engagement of users identified through this corpus. These strategies draw together and build on related conceptions and motivations for the adoption of engagement and have often emerged within the context of a particular discipline. These strategies provide examples of how particular conceptions of engagement can be employed within a range of design contexts and may be useful to consider in new design projects.

6.1 Ensuring Usability

Engaging experiences are built on usable interaction. These systems satisfy the basic needs of use, are easy to use, are reliable, are learnable, and result in the effective use of users' time and resources (O'Brien and Toms 2008).

Usability. Although usability was studied infrequently within this sample, one study of an e-learning system for hospital patients ($n = 281$) found that "the user's intention to continue usage was predominantly determined by satisfaction with the system and perceived performance" (Chou et al. 2012). A study of playability, usability and 'long-term' engagement in games found that

Table 4. Application Contexts with Respect to Which Engagement Has Been Studied (a Single Publication May Cover More Than One)

Application	Mentions
Gaming	56
General Learning	32
Online Learning	27
Social Media	15
Classroom Learning	14
Distance Learning	8
Virtual Learning Environments	8
Gamification	7
Virtual Agents	6
Algorithm Visualisation	6
Online Networks	6
Online Search	5
Online Services	5
General Education	5
Website Use	5
Museum Exhibits	5
Website Design	5
Social Networks	4
Robotic Agents	4
eGovernment	4
IVA Salesperson	3
Presentations	3
Reading	3
Robotic Tutors	3
Programming	3
Online Shopping	2
Storytelling	2
Exercise Support	2
General Computer Use	2
Robotic Companions	2

engaging experiences can arise despite usability defects if those problems are limited in frequency and the Density of Usability Defects (DUD) is low (Febretti and Garzotto 2009).

Feedback. Prompt and accurate feedback supports engagement. One study examined the impact of performance-related feedback and found that positive feedback motivated users to higher task performance (Fairclough et al. 2013). Negative feedback did not lead to disengagement, which the authors propose could be due to the abstract nature of the task and a lack of negative consequences for failure. As a study of user attitudes towards online social experiences found, "pressure to perform" can be "both a good thing and a bad thing" (Social Computing Research Group 2005). Another study manipulated the *immediacy cues* displayed by a humanlike robot as it told stories (Szafir and Mutlu 2012). Immediacy cues were defined as "actions taken by speakers to decrease the psychological distance between themselves and their listeners." More adaptive, humanlike immediacy behaviours led to improved recall, as well as greater rapport and motivation among female participants (Szafir and Mutlu 2012).

Aesthetics. Given the ubiquity of high-quality games and other commercial systems, many users today also hold aesthetic expectations that may need to be met for engagement to ensue (van Vugt et al. 2007).

6.2 Managing User Resources

Engagement, as a measure of interaction, reflects both user and system performance. This has led to its adoption as a means of 'managing' interaction, through real-time adaptation to the user. This strategy is most relevant to well-defined tasks with measurable outcomes. The measurable proxies for engagement in these contexts are often cognitive in nature, examples being difficulty (Castellano et al. 2009), cognitive load (Oviatt et al. 2008), and workload (Galán and Beal 2012).

Challenge, Cognitive Load, and Workload. One study tested the implicit use of speech amplitude and pen pressure to engage a computer assistant while reducing cognitive load (Oviatt et al. 2008). During a series of maths questions, 86% of intended interactions were correctly identified through speech and 75.2% by pen pressure, compared to human judgement. The reliability of the speech system also improved during the session. Users adapted their speech to the system, often unconsciously according to post-session interviews.

Another system used EEG measures of users' engagement and workload to predict whether maths problems would be answered correctly (Galán and Beal 2012). Sixteen college students solved 8 maths problems (4 easy and 4 hard). A prediction accuracy of 87% was achieved using the 'most informative' signals from both data streams. Workload scores were significantly higher for more difficult problems, while engagement scores showed no change, suggesting that engagement and workload could be treated as independent variables.

Another study found that playing games via a Brain Computer Interface (BCI) introduced a higher workload than Automated Speech Recognition (ASR) control, although both systems rated below the median on the Game Engagement Questionnaire (Gürkök et al. 2011). Other work has adopted workload as a direct proxy for engagement, including a computational model to balance users' task engagement (workload level) and automation (awareness level) (Klein and Van Lambalgen 2011), and a five-stage framework for the measurement of users' cognitive engagement online, based on the concept of human mental workload (Longo 2011).

Monitoring Engagement. When we talk about the measurement of engagement, often we are not talking solely of assessment for research but of processes that could come to form a part of users' daily lives. It is therefore essential to consider the acceptability of user monitoring and to respect users' privacy and autonomy. Systems designed to maintain user engagement often do so to optimise a particular outcome, "social interaction or efficiency of task completion," for example (Akker et al. 2009). However, increased engagement does not necessarily "imply improved efficiency in terms of task performance and vice versa" (Akker et al. 2009). Specific outcomes require appropriate forms of engagement. A system for public feedback concerning public spaces was designed to engage users as "creative observers rather than mere information seekers," for example (Whittle et al. 2010).

Adaptive systems might not focus solely on the maintenance of engagement but also on signs of disengagement, discontinuities in interaction. *Interruptibility* has been examined with respect to task-focused systems, as in the development of an algorithm to interrupt programmers at the optimal moment (Fogarty et al. 2005). Adaptation to user performance must be informed by sufficient context. For example, if a user's engagement with a game drops "because the player is bored, then the appropriate response from the system is to challenge the player." If the decline in engagement is due to "excessive game difficulty," then this "requires a different adaptive response, e.g. to assist the player" (Fairclough et al. 2013).

6.3 Immersing Users

One strategy for engaging users focuses on their immersion (deep psychological absorption) in experience through interaction.

Immersion. Immersion is often adopted as a metonym of engagement, particularly in the contexts of gaming (Brown and Cairns 2004; Carrigy et al. 2010) and virtual environments (Dow 2007). As is the case with engagement, multiple theories and interpretations of immersion exist.

Immersion has been described as characterised by a sense of ease and familiarity, a more *passive* experience than engagement—a comparatively conscious and effortful process (Douglas and Hargadon 2000). The same authors state that while flow hovers on a "continuum between immersion and engagement," "immersion and engagement are neither mutually exclusive properties nor polar opposites." The developers of a location-based mobile game also describe engagement as more active than immersion but 'total immersion' as an experience similar to flow (Carrigy et al. 2010).

In contrast, Swift et al. state that "a participant can be engaged in an activity without being immersed but cannot be immersed without being engaged" (Swift et al. 2010). This kind of *hierarchical* comparison features elsewhere, as in the statement that "it is not so much that involvement is necessary for learning, but that a certain amount of learning is required before being able to experience deeper levels of involvement" (Iacovides 2009).

One interpretation of immersion links the term to the "the *sensation of being surrounded* by a completely other reality … the experience of being transported to an elaborate simulated place" rather than to absorption in the present reality or task (see Murray as cited by Carrigy et al. (2010)). This distinction between immersion as "deep absorption" and "traversable space habitation" is respected by the Digital Game Experience Model (DGEM), which describes six *frames*, or modalities of meaning, that are gradually *internalised* by the player during the process of play (Calleja 2007).

Other perspectives focus on immersion as a psychological *state*, including Witmer's view of immersion as "influenced by the immersive tendencies of the individual," Salen and Zimmerman's description of engagement as a process of double consciousness, and Ermi and Mayra's sensory, challenge-based, and imaginative (SCI) immersion model (see Carrigy et al. (2010)). Another possible distinction is between immersion, characterised by "loss of self-awareness, loss of social awareness, and loss of game awareness," and what is termed *neo-immersion*, involving "awareness of self, awareness of others, and awareness of the game" (Whitson et al. 2008).

Brown and Cairns define three levels of immersion, denoted *engagement*, *engrossment* and *total immersion*, drawing on a grounded theory analysis of the interviews of seven gamers following time spent playing their favourite game (Brown and Cairns 2004). The authors describe the fleeting nature of total immersion as the distinguishing feature between it and the flow state. Brown and Cairn's conception of immersion is linked closely to the idea that controls should be as close to invisible as possible (Jacucci et al. 2010; Turner 2010).

Brown and Cairn's model provides a strategy for user engagement by outlining the barriers between each 'depth of interaction.' Barriers of access (related to the game controls and feedback), time, effort (investment, expectation of rewards) and attention (a willingness to concentrate) pertain to the first state, game construction (visuals, interesting tasks, plot) to the second, and empathy and atmosphere (barriers to presence) to the third (Brown and Cairns 2004).

Presence. Presence is closely linked to immersion and also to the hypothesis that greater invisibility of controls leads to increased immersion (Brown and Cairns 2004). This concept is often encountered in the context of augmented or virtual reality. Biocca's three forms of presence, physical, social, and self, suggest, however, that this term cannot be tied to a single conception (see Dow et al. (2007)). Presence has also been described as *perceptual immersion* but not *psychological immersion* (Seah and Cairns 2008).

Dow also views presence as 'perceptual immersion' distinct from engagement; "a user's involvement or interest in the content independent of the medium" (Dow 2007) and further states that while the aim of virtual and augmented reality systems is to make users feel "as if they are 'there"' or to "create the 'illusion of nonmediation,"' this can fail "to recognize the notion of actually engaging the user" (Dow 2007). This claim is supported by a study of three different implementations of an interactive drama using text-input, speech, and augmented reality (AR) (Dow et al. 2007). Only half of players (6 of 12) preferred the AR version of the system, citing a desire for more distance from the game to engage more comfortably with it. This suggests that "more 'natural' or 'transparent' interfaces, where the medium fades to the background, will not necessarily lead to a compelling game or entertainment experience" (Dow 2007).

Involvement. Involvement, a similar concept to immersion, has also been compared to engagement (Kappelman 1995). Contrasting the two terms, it has been claimed that engagement implies a degree of intrinsic interest, whereas involvement may occur even when the user experiences no enjoyment (Webster and Ahuja 2006).

6.4 Engaging Users Emotionally

Affective computing research has strong parallels to work on engagement, given the motivation to produce interactive systems with representations of fuzzy states (Beale and Creed 2009). However, engagement has itself also been described as an affective state or emotion. The measurement of engagement as an emotional response has been used to support the design of engaging experiences.

Defining Affect. Affect is most commonly described as the the experience of emotion, composed of the dimensions of valence and arousal (D'Mello et al. 2010). The 9×9 affect and arousal grid, for example, has been directly applied to the measurement of engagement in the context of collaborative lecturing by human and computer tutors (D'Mello et al. 2010). However, affect has also been annotated as composed of three dimensions, valence, arousal, and power of control (Bianchi-Berthouze et al. 2007), defined as a combination of short-term emotion and longer-term mood (Hart et al. 2012) and examined using appraisal theory (Turner 2010). An alternative view positions engagement (as attention) as a moderator of affect, filtering information as it is perceived. One study, in the context of art viewing, found that "momentary engagement overrides the effect of mood on ambient/focal attention" (Biele et al. 2013).

Measuring Affect and Engagement. The measurement of affect and engagement share many of the same challenges and techniques. In the realm of affective cinema, for example, engagement has been assessed as 'positive excitation' using galvanic skin response, electroencephalogram, and automatic facial tracking measures (Abadi et al. 2013). Each modality was found to significantly encode viewer-engagement. GSR and EEG measures contributed comparably, and all three data sources combined resulted in the best performance.

In the context of two insightful studies of audience engagement, engagement was described as "related to attention and interest" but operationalised as valence and arousal (Latulipe et al. 2011). In the first study, three choreographers and four theatre directors were shown video of a performance (dance or theatre) alongside a timeline of previous viewers' GSR (indicating arousal) (Latulipe et al. 2011). The software allowed users to vary the time period across which an average GSR response was calculated. This practice highlighted the need to differentiate between *semantic-chunking* and *stimulus-response* interpretations of data. The narrative structure of a live performance means that interpreting momentary data as though at "each second, audience members are responding to the thing they just saw happen in the previous second" is often erroneous, as stated expressly by participants.

A second study examined audience reports of engagement. Nine participants watched a video of an 11-minute dance performance in an immersive environment while wearing a GSR sensor and manipulating a slider to indicate their level of engagement. Multiple 'vocabularies of engagement' were tested. With respect to a scale comprising *'No Engagement to High Engagement,'* it was found that users "could not detach valence from the word, and tended to only rate themselves as being engaged when they liked what they saw. Others just didn't really seem to know what we meant by engagement, and still others didn't seem to know how engaged they were" (Latulipe et al. 2011). Other vocabularies included *'Love it! to Hate it!'* and *'No Emotional Reaction to Strong Emotional Reaction.'*

When later presented with a graph of their responses and asked to explain their ratings, those in the emotional reaction group did not provide as many details about the performance, and several reported difficulty using the scale. Those in the Love-Hate group could "lower their love-hate rating if something confused them" but "the mapping to the ER scale" was "less clear." This was the only work within this corpus that examined users' interpretation of engagement despite the potential significance of these differences, particularly in the case of self-report.

6.5 Inspiring Fun

Engagement has been conceived not only as utilitarian but also as driven by enjoyment, gamification, escapism, and fun; "the state of mind that we must attain in order to enjoy a representation of an action," entailing "a kind of playfulness—that ability to fool around, to spin out 'what if' scenarios" (Laurel 1991; Webster and Ho 1997). *Ludic engagement* has been defined as "a precondition to play" (Brooks 2013). Enjoyment has been described as a component of engagement (Rozendaal et al. 2008) and characterised as composed of multiple constructs, including engagement, positive affect, and fulfilment (see Warner's model, as cited by Lin et al. (2012)).

Humour. Humour has been shown to support engagement. The addition of a sidekick robot to a child–robot interaction increased the attention users paid to spoken dialogue (Vázquez et al. 2014). Twice as many participants laughed at least once. Analysis within the context of video games concluded that "humour itself stimulates engagement and provides a pleasurable experience" (Dormann et al. 2006).

Gamification. As an approach to designing enjoyable experiences, gamification is particularly popular. Primary categories of motivational incentives are *social psychological*, including social facilitation and loafing effects, and *economic* (Liu et al. 2011). Although economic motives may increase the quantity of "work" completed, they cannot be guaranteed to increase quality (Liu et al. 2011). The effects can be transitory, "participants can feel manipulated," "little or no transfer can occur if behavior is only driven by rewards," and "if the reward vanishes so does the behavior" (Domínguez et al. 2013). In one attempt to 'gamify' an e-learning experience, the authors' use of competition as a motivator was not well received by all students, one participant stating that "it would be more interesting to improve the traditional version, instead of making competitions" (Domínguez et al. 2013).

A study of children's engagement with LIEKSAMYST, a hypercontextualised game (HCG) in a museum environment revealed four motivational factors; curiosity, challenge, fantasy, and personal control (Islas Sedano et al. 2013). The authors stress the importance of user freedom and voluntary participation to engagement: "If a game has to be played as part of a prescribed school assignment, then the pupils (or players) do not access that game voluntarily. Instead the game is viewed as a task that the pupils have to complete within the school milieu."

Users' time spent playing games can also be strongly influenced by *negative reasons for playing*, however, suggesting that negative experiences can also act as catalysts for enjoyment and engagement (Boyle et al. 2012).

6.6 Enabling Exploration

The use of a product entails more than accomplishing a single goal, extending to the engagement of additional senses, actions, and feelings (Chou and Conley 2011). Engaged reading, for example, has been described as "not a mere information-extracting process rather an experience encompassing a wider range of activities," including "book selection, reading, imagination, learning, multisensory exploration, confrontation with the peers, etc" (Colombo and Landoni 2011). Tasks have been classified as experiential or goal-directed (Rozendaal et al. 2007, 2008) and ill or well defined (Brooks 2013; Goldberg et al. 2011). Experiential, or ill-defined tasks can result in richer experiences, allow exploration, and are more likely to prove engaging (Brooks 2013; Kucirkova et al. 2014).

Richness. The richness of an interactive experience can be defined in terms of the diversity and evolution of its affordances and content and the control provided to the user. The RC&E framework models engagement according to the experience of richness and control. Within this framework, richness is defined as the "complexity of thoughts, actions and perceptions as evoked during the activity" and control as the "effort that is experienced in the selection and attainment of goals" (Rozendaal et al. 2008). Engagement is defined as the square root of the product of richness and control.

In a study of user engagement with a digital table-top game, richness was controlled by modifying the variety of ball and user behaviours, level of colour, detail, and asymmetry of the visual design, and control by manipulating the hand-eye coordination required and by the addition of redundant visual information (Rozendaal et al. 2007). It was found that richness commanded more of an impact on engagement during experiential tasks while control had a greater impact during goal-oriented tasks. When a user is presented with a well-defined task, the ease with which this can be accomplished is prioritised. A lack of richness can lead to boredom and a lack of control to anxiety (Rozendaal et al. 2009).

The study of *narrative* is related to the richness of experience. Spatial containment, causality, skill-based interaction, causality of dialogue, illusion of intelligence, and invisibility of the medium are considered to promote engagement in narrative multimedia (Mallon and Webb 2000). However, a potential conflict exists between the provision of *control* to the user and disruption to the narrative flow. Adams writes that although "interactivity and storytelling" are not necessarily mutually exclusive "the more you have of one, the less you're going to have of the other" (Adams 1999).

Novelty. Exploration requires novelty. Flow theory views novelty not only as related to first use but as a characteristic of interaction which can be continually reproduced (Cowley et al. 2008). Engagement and novelty may together inform a user's decision to participate in an experience (Cowley et al. 2008). However, novelty has only rarely been examined with respect to engagement (Bianchi-Berthouze et al. 2007; O'Brien and Toms 2010b; Webster and Ho 1997).

6.7 Supporting Social Connectedness

Some of the strongest motivations to engage with technology are social in nature. Social engagement has been described as "the first stage of social intercourse" (Singletary and Starner 2001) and also as "not just about how a single interaction unfolds, but about how and why people develop a relationship with a platform or service and integrate it into their lives" (Jaimes et al. 2011a, 2011b). The link between social interaction and engagement has been studied within sociology (Goffman et al. 1978) but also with respect to technologies for gaming (Abreu et al. 2013; Lindley et al. 2008; Oksanen 2013; Rozendaal et al. 2009), learning (McClure 2013), social networks (Freyne et al. 2009; Kirman et al. 2010), and joint media engagement (Ballagas et al. 2013).

Social Strategies. It has been found that the strongest motivations for participation in social networks are associated with a sense of belonging and influence, specifically efficacy, anticipated

reciprocity, and increased reputation and recognition online (Freyne et al. 2009). One study found that users of a social network who received people recommendations were more likely to return to the site. Those who received recommendations to active people were most likely to return (Freyne et al. 2009).

Mutual engagement has also been studied with respect to Daisyfield, a collaborative music making program that allows users to create music loops in a shared visual space (Bryan-Kinns 2013). Participants were most mutually engaged when granted either the provision of identity cues or indications of each other's focus but not both. The author suggests that "maybe there was an expectation that others would take more notice of their work when they could see each others' loci of attention," leading to "increased expectations on others—a form of social contract."

Another study of collaborative music making identified three 'qualitatively different engagement relationships'—individual, unilateral, and bilateral (Swift et al. 2010). Participants in this study commented that they viewed individual engagement as a potential barrier to group enjoyment. The use of *network theory* and real-time visualisation of these relationships was proposed as a means to support engagement.

Social Presence. The link between social presence and engagement has also been studied, including with respect to education (Wise et al. 2004) and human–robot interaction (Choi et al. 2014). Users have been said to feel socially present when "interdependent on other people inhabiting the same environment" or when they "intensely feel the engagement with the other agents" (Martino et al. 2009). Biocca et al. describe three dimensions of social presence: co-presence, psychological involvement, and behavioural engagement (see Martino et al. (2009)). Social presence emphasises the embodied nature of engagement.

6.8 Enabling Optimal Experience

Engagement has also been examined as a means of assessing progress towards a state of 'optimal experience,' a target for designers. The prominent adoption of flow theory often reflects this perspective (Cowley et al. 2008).

The Flow State. Flow and engagement states are often viewed as synonymous. Engagement has also been described as a subset of flow and a more *passive state* that is therefore more appropriate than flow when the user experiences less control (Webster and Ahuja 2006). It has also been proposed that games that do not set clear goals, as required for flow, can still be immersive and that negative and even frustrating experiences do not necessarily lead to decreased immersion (Seah and Cairns 2008).

Systems that adapt to the user have been explored as a means of facilitating the flow state. This includes adaptive algorithms that determine when a player should be allowed to progress in a learning game (Lomas et al. 2012) and a model that adapts to the gameplayer, not by adapting the level of challenge but by changing the way the player perceives the results of his or her actions, with the aim of improving player confidence (Van Der Spek 2012).

Flow theory is typically applied with respect to short timescales and has likely contributed to the prominence of situated experimentation within the engagement literature. However, it has also been suggested that flow theory could be applied to interaction "over a much longer time scale" (Seddon et al. 2008).

6.9 Promoting Repeated Use

Users come to interact with products and services through a combination of personal volition and environmental factors. However, many technologies are designed to support active rather than passive users (Fischer and Benford 2009; Karavirta and Korhonen 2006; Webster and Ho 1997) and

engagement "both in the moment and over time" (Lamberty 2004). For certain combinations of systems and users, long-term engagement can develop of its own accord, where the psychological needs of users are met, meaning and value are provided, and the burden on users is low. However, the less intrinsically engaging a technology proves, the more likely proactive strategies may be required to enable a habit of use. These strategies can include mobile phone notifications, email reminders, scheduled incentives, and reward tiers (Gençer et al. 2013).

Addiction. While negative patterns of engagement can take many forms, it is game addiction that has received the most significant focus. Addiction and engagement have been described as "attitudes to the general experience of playing" and immersion as closer to "the actual experience of specific instances of play" (Seah and Cairns 2008). Several scales have been developed to assess addiction and its relationship to engagement, including Brown's Addiction Checklist, Charlton's Computer Apathy and Anxiety Scale (CAAS), Tellegen's Absorption Scale (Seah and Cairns 2008), and the Addiction-Engagement Questionnaire (Metcalf and Pammer 2011). An attentional bias for gaming-related words has also been identified among addicted online game players (Metcalf and Pammer 2011).

One study examined gaming addiction among 1,332 South Korean middle and high-school students using a custom 65-item questionnaire (Seok and DaCosta 2012). Between 1.7% and 25.5% of the sample group were classified as addicted depending on the criteria and cut-off threshold employed. However, the authors stress that further work is needed to reach a consensus on criteria for distinguishing between non-pathological and pathological gameplay if reliable prevalence rates are to be obtained.

Many popular technologies are now designed to attract and maintain user engagement, including mobile games, social networks, and news applications. These systems provide content that is personally tailored, packaged into small chunks, updates frequently and unpredictably and whose delivery is activated at the press of a button. There are clear parallels between these strategies for engagement and those employed in the design of the slot machines of Las Vegas (Schüll 2012).

7 DISCUSSION

The findings of this review support further reflection on the past, present, and future adoption of engagement.

7.1 Domains of Knowledge

Interpretations of engagement extend beyond what we might think of primarily as 'user engagement.' Returning to the issue of context-specific definitions raised in Section 3, considering different domains of knowledge can provide new insights.

Conversational Engagement. Forward-looking work on engagement is to be found in the study of human–computer conversation, including the development of robots and virtual agents (Baecker et al. 2006; Fagen and Kamin 2013; Oertel 2013; Oertel and Salvi 2013; Rich et al. 2010; Sidner and Dzikovska 2002; Sidner et al. 2004, 2005; Xu et al. 2013). In this domain, interaction is often interpreted though conversational analysis. This perspective features a useful distinction between backward and forward-looking forms of engagement, the first referring to grounding behaviours, "what is understood up to the present utterance," and the latter to users' need to "be connected and aware in the interaction" (Sidner et al. 2005).

Information Visualization Engagement. With respect to information visualisation, user engagement has been explored as a means of balancing the design goals of *cognitive efficiency* and *learning*, "a trade-off between efficiency and beneficial obstructions" that promote active processing (Hullman et al. 2011). The ITiCSE Engagement Taxonomy characterizes engagement as a 'type'

or 'depth' of interaction, defining six forms; No Viewing, Viewing, Responding, Changing, Constructing, and Presenting (Naps et al. 2002). This taxonomy has been applied in a number of design scenarios (Karavirta and Korhonen 2006; Urquiza-Fuentes and Velázquez-Iturbide 2012) and attempts made to extend it (Myller et al. 2009).

Learning Engagement. Definitions of learning engagement are often brief (Barkatsas et al. 2009; Blasco-Arcas et al. 2013; Cocea and Weibelzahl 2007; Grimes et al. 2005; Hu and Hui 2012; McCay-Peet et al. 2012). It has also been argued in this context that research often "essentializes engagement," ignoring the effects of gender, socio-cultural, ethnic, and economic status (Zyngier 2007, 2008). *School engagement* has been described as malleable, responsive to contextual features, amenable to environmental change and as a 'meta' construct (Fredricks et al. 2004). Engagement has been construed by practising educators as a property of materials, as learner attentiveness, as interaction, and as increasingly legitimate participation within a community of practice (Notess 2008). With respect to this last conception, engagement is "the result of learning as much as the means of learning."

Gamification is often employed as a strategy for student engagement. Although there have been attempts to guide designers (Schuurink et al. 2008), this approach has not always met with success. A systematic review of computer game and serious game use found no strong evidence to suggest that games lead to more effective learning (Connolly et al. 2012). A weakness of games designed for learning may be that they do not sufficiently inspire *reflection.* Avoiding "opportunities that users might take to reflect on their actions" has even been described as a trick used by designers to maintain player engagement (Whitson et al. 2008). It could be that *slower* forms of interaction are required to promote complex cognitive processes such as understanding (Kuznetsov et al. 2013).

Civic Engagement. Civic engagement is a broad field of research, encompassing e-government, citizen sensing projects, gendered engagement in STEM subjects, community-based activism, and the generation of social capital (Kim and Kleinschmit 2012). Definitions of civic engagement have been proposed by a number of authors (Farnham et al. 2012; Nepal et al. 2012; Park 2006; Taylor et al. 2012). However, it is often in a transitory fashion that references to user engagement with technology are currently encountered within this domain.

Wellbeing Engagement. Engagement has also been studied with respect to wellbeing. This includes the design of an intervention to boost social engagement between residents of retirement homes (Linnemeier et al. 2012) and a serious game to tackle work-related stress while increasing work-related engagement (Wiezer et al. 2013). One interpretation of engagement in this context is "a kind of mindfulness requiring cognitive effort and deep processing of new information" (Xie et al. 2008). However, it has been suggested that although "characteristics such as feedback, control and interactivity may be associated with systems that are likely to promote engagement, they may not necessarily promote the mindful kind" (Pearce and Pardo 2008). Studying engagement can provide insight into the optimal role of technologies within our lives, possibly supporting a shift from "proactive computing to proactive people; where UbiComp technologies are designed not to do things for people but to engage them more actively in what they currently do" (Rogers 2006).

7.2 What's Missing?

A number of gaps exist within the engagement literature.

Engagement in the Real World. Most studies of engagement take place in constrained laboratory environments, establishing internal validity but often neglecting ecological validity. We echo a call for research in real-world contexts; "open, relatively unconstrained environments, where multiple people with different needs, goals and long-term plans may enter, interact and leave the observable world" (Bohus and Horvitz 2009a, 2009b, 2009c).

Voluntary Engagement.

> Providing participants with instructions, such as 'Go interact with this system', or 'Go join the existing interaction' can significantly prime and alter the engagement behaviors they would otherwise display. (Bohus and Horvitz 2009c)

A significant gap in the literature concerns voluntary engagement. Supporting voluntary participation in user studies is challenging but an essential component of engagement research (Bohus and Horvitz 2009c; Islas Sedano et al. 2013). A focus on voluntary use is needed to shift design towards more 'realistic' forms of engagement, as expressed in the *focused-casual continuum* (Pohl and Murray-Smith 2013). Rather than focusing primarily on achieving high levels of engagement, design should support users' choice of "the level of interaction depending on the situation, so that they can also choose to casually interact" (Pohl and Murray-Smith 2013). Novel methods of recruitment, such as Google Adwords (Colbert and Boodoo 2011), or mobile applications for public use (Killingsworth and Gilbert 2010) require further exploration. The study of engagement should allow for realistic means of engagement, yet this is rare.

Engagement over Time. Longitudinal research is currently overshadowed by a multitude of brief and situated experiments. Definitions of long-term engagement include the "maintenance of user adherence to a desired interaction usage pattern" (Bickmore et al. 2009) and "the degree of voluntary use of a system along a wide period of time (i.e., weeks, months, or years), involving dozens, if not thousands, of interactions, each one spanning for significantly longer than few seconds or minutes" (Febretti and Garzotto 2009). Longitudinal engagement effectively has a vocabulary all of its own; *patterns, trajectories, sporadic, immediate, periodic, shaped, sustainable.* These terms are empowering in that they tie often verbose conceptions of engagement to a real-world context. Experience is cumulative (Carrigy et al. 2010) motivations for use evolve over time (Naps et al. 2002; Snow et al. 2013; van Vugt et al. 2006), and so engagement cannot be fully understood without longitudinal analysis (Chen et al. 2011).

Long-term research has produced insightful results. A meta-study found that "students' utilization patterns of visualizations had a much greater impact on their learning success—and therefore on the tool's educational effectiveness—than the quality of the visualizations" (Hundhausen et al. (2002) as cited by Isohanni and Knobelsdorf (2011)). Another study found that increased engagement with virtual agents designed to support behaviour change over time in fact led to decreased exercise behaviour (Bickmore et al. 2010).

However, a call for increased analysis of longitudinal engagement does not imply that continuous or consistent engagement is always the appropriate design goal. Also lacking within the literature is discussion of the processes of disengagement, stepped models of engagement and non-use.

Engagement with Design. Another gap within the literature is attention to the fit between engagement and the design process.

The design of engaging experiences rests on the assessment of user engagement. In Section 5 we described the variety of approaches to measurement. However, the integration of these methods within a process of design has received little attention. While several user engagement questionnaires have been rigorously developed, it is not clear how useful these measures have been to practising designers. Of particular interest would be an exploration of how the UES (O'Brien and Toms 2010b) might fit within an iterative design process, in comparison to the ESQ (Schoenau-Fog 2011) for example. Depth of analysis, efficiency of application and ease of interpretation are all desirable qualities for such measures. Would a One Minute Questionnaire (King and Robinson 2009) provide actionable insight for engagement? Is asking users 'Was this an engaging experience? If not/so, why?' as useful a means of assessment as validated questionnaires, interviews, behaviour

logging or observation with respect to particular design goals? It is clear that there is room for further study of the value of different methods of evaluation.

Many of the barriers to the adoption of engagement are familiar to designers, including the challenge of highlighting "relevant factors of engagement while still allowing designers to use their intuition and creativity" (Rozendaal et al. 2008) and the lack of optimal solutions to design decisions (Harteveld et al. 2011). The field of design thinking has long considered such challenges (Rittel and Webber 1973; Simon 1969) and additional consideration of this perspective, while beyond the scope of this article, may support design for engagement.

7.3 Understanding Engagement

Understanding engagement requires embracing a diverse methodological toolkit with an awareness of the contribution and limitations of each perspective. These challenges have been encountered elsewhere within HCI, with respect to user satisfaction (Lindgaard and Dudek 2003), usability (Hornbæk 2006), and emotion (Hudlicka 2008), for example. In this section of our discussion, we propose several means of negotiating the complexity of these concepts.

Strive for Clarity of Expression. Engagement is a term we use to share meaning with respect to certain qualities of experience. However, language is flexible and interpretation reliant on cultural and professional bias. It is unhelpful to find ourselves caught up in questions such as whether the statement that "a student is engaged by a programming project, but is interested in computer science" (Hansen and Eddy 2007) is 'true,' whether a related concept such as 'interest' is a feature of engagement, an outcome, or a contributing factor, or between antonymic (engagement 1003 v. disengagement) and valenced (positive v. negative).

Clearly articulating what we mean by engagement requires us to consider the concept's theoretical foundations (Section 3), the ontological and epistemological framing of our interpretation within an HCI ecology (Section 4) and our motivations for the use of the concept (Section 5.3).

Learn from Parallel Trends. There has been a call for a 'turn to practice' in the study of user experience, away from the dominant perspective of rationalism which can present "an obstacle to thinking about technology by reifying technological artefacts as objects of study apart from their making and use" (McCarthy and Wright 2004). The rationalist perspective is also prominent within affective computing, where researchers model emotions as discretised states, a "transformation from signal to symbol," tackling emotion as a "problem of representation" that can be addressed by state-based models (Picard 2000). Similarly, there has been a call to look to the 'social-interactionist' alternative, acknowledging the social and cultural origins of emotion and its interpretation as experience, not just as an objective, measurable unit (Boehner et al. 2005).

User engagement research has also been predominately rationalist to date within Computer Science, as evidenced by both theory (see Table 2) and methodology (see Table 3). This is not necessarily an 'unfavourable' finding. However, we would echo, with respect to engagement, the call for "an appreciation not only of how emotion as a phenomenon is measured but also how measures make the phenomenon of emotion" (Boehner et al. 2005).

Embrace Methodological Diversity. Certain technologies realise a greater range of experience (emotional, cognitive, behavioural, and social) than others. Multiple approaches to assessment are often essential to understanding engagement in terms of such complex characteristics. The link among conceptions of engagement, experience, and their component parts can prove confusing given the breadth and diversity of the engagement literature. However, with clarity of expression, this need not be the case. We measure resting heart-rate as indicative of overall health without any confusion concerning its limitations. The implications of engagement as an indicator of user experience can be interpreted in similar terms.

Don't Confuse Models with Reality. We must also take care when creating models of engagement to acknowledge their limitations. Many approaches we deem rational and objective rely on human judgement for establishing a ground truth, often through self-report or annotation. Even as humans we can only make inferences about another's state of engagement. It is important to avoid committing a 'fallacy of reification,' mistaking a model of engagement for 'the concept itself.' A map is not the territory it represents (Korzybski 1933). Recognising how our perspective on engagement fits within an HCI ecology can clarify our framing and draw attention to our assumptions (see Section 4).

Focus on Fit for Purpose. Acknowledging the conceptual nature of engagement does not mean that invalid approaches to its assessment do not exist. The established metrics of validity, reliability, and generalisability maintain their relevance. It is also important to note that once a user becomes aware of the use of engagement as an outcome measure, it can cease to represent an accurate metric (Goodhart 1975).

A focus on engagement can obscure design for other objectives. Certain definitions of engagement infer a direct link between conception and measurement. For example, it has been argued that "[i]f engagement to you is repeat visitors by visitors then call it Visit Frequency, don't call it engagement" (Kaushik 2007). More complex conceptions may require significant inference. However, any one interpretation of engagement is unlikely fit for all purposes and greater engagement does not always imply improved learning, wellbeing, or experience (Bickmore et al. 2010; Connolly et al. 2012).

Acknowledge Complexity. Engagement is a 'device' we adopt to facilitate a particular perspective on interaction and experience. It does not exist predefined in nature, nor is there one universally 'optimal' approach to its understanding. The question we ask should not be 'what is engagement?' but 'what interpretation of engagement is best suited to this context and purpose?' while justifying this choice, as discussed in Section 3.1. We should move away from unhelpful and unfounded discussion of what engagement 'is' towards how engagement is 'interpreted' and 'measured.'

7.4 The Value of Engagement

Engagement is a popular concept. However, there has been very little discussion of the value it provides. We explore the implicit value of the concept below, returning to the motivations listed in Section 5.3.

Value to Research. Engagement is frequently adopted not just as an outcome in itself but as **conducive** to other aims. It is both an end and a means to an end. Engagement is popular in educational research, for example, due to the assumption that greater engagement with a system for e-learning is likely to support improved learning outcomes and, in wellbeing research, behavioural outcomes. Engagement is seen as contributing to a larger goal, such as wellbeing, happiness, learning, or task efficacy. This mediating relationship is one of the advantages of engagement over the concept of experience. It supports a reasoned connection to other valued concepts.

Engagement is viewed as a **flexible** concept. This can contribute to ambiguity but makes engagement relevant to a variety of contexts and purposes. It also supports multiple levels of analysis. Engagement can be viewed as ephemeral and visceral in nature but can also be linked to, and have important consequences for, more abstract cognitive processes, including not just learning but reflection (Whitson et al. 2008), empathy (Hall et al. 2005), and understanding (Davies 2002). This means that engagement can provide insight into user experience at multiple depths, spanning the gap between theory and practice. This turns our attention to a spectrum of use, degrees of engagement and disengagement, as well as change over time.

Value to Design and Development. One perspective on engagement might view it as the process by which we **frame** experience. This provides a grammar for discussing patterns of engagement and differences between users—a grammar that can help inform design.

Evidence of voluntary engagement with a system indicates that the system is not just usable but **useful**. It provides value, in some form, to its user. User engagement can therefore be viewed as a measure of the 'health' of an iteractive system, of its value, as inferred by proxy of its measurable components, not blood pressure and heart-rate, but interaction and subjective experience. Engagement is seen to imbue many of the positive features of experience and as presenting easily measurable forms. However, there are limits to such analysis. Engagement is most insightful when use of a system is voluntary and takes place over time. It is not always positive in its outcomes, motivations, or design, as evidenced by technologically driven distraction, social withdrawal, and addiction.

Knowledge of user engagement allows designers to grasp the value of their products to the user, and sufficient detail can provide **actionable** insights to support the iteration of design. Whether engagement, and of what kind, is the appropriate design goal is a determination that needs to be made. However, the concept offers a pathway for action, a target, in a way that the amorphous concept of experience may not.

Value to the User. Engagement represents the focus of one's conscious experience. The redistribution of this capital is one of the key roles technology plays in our lives. Engagement can also be viewed as **empowering**, emphasising users' autonomy and control. A subtle difference between 'use' and 'engagement' can be discerned. Engagement tends to emphasise a user's autonomy, needs, motivations, and the promise of a positive experience. Use can appear disembodied in comparison. A focus on engagement presents technology as 'used' by humans to varying degrees of intensity, pushing us to examine the role we want technologies to play in our lives.

7.5 Recent Trends in the Engagement Literature

Turning to the comparison corpus examined in 2018, authors continue to refer to the persistent challenge of understanding and measuring engagement (Arapakis et al. 2014; de Oliveira et al. 2016; Drutsa et al. 2015; Hamari et al. 2016). Ray et al. write that "[a]lthough researchers implicitly concur on the significance of engagement in the context of online communities, the notion of engagement itself remains relatively little understood in the information systems literature" (Ray et al. 2014).

As prior to 2014, the largest category of research pertains to online technologies (44.4%), although less now examines personal computers (16.7%). Much research in the 2018 sample concerns learning applications (22.2%), social media or online communities (16.7%), and health (11.1%). This most likely reflects increased use of wearable trackers, and a shift to online platforms, including Massive Open Online Courses (MOOCs), enabled by HTML5. Reza Habibi et al. describe engagement as "the Holy Grail of social media" (Habibi et al. 2014), and the literature features increased reference to 'community,' 'customer,' and 'brand' engagement (de Oliveira et al. 2016; Habibi et al. 2014; Lim et al. 2015). In line with this trend, Preist et al., for example, propose 'normification' as an alternative to gamification, focusing on "ideas of collective engagement," encouraging "normalising behaviour where community members aim to emulate others in the community and behave similarly to them" (Preist et al. 2014).

Of those publications examined in the period 2014 to 2018, 61.2% provided no definition of engagement (compared to 65% prior to 2014), and 63.8% of papers also make no reference to theory. The most cited theory remained flow theory (13.8%) at a very similar rate to that prior to 2014 (14.2%). Behaviour logging (55.6%) overtook questionnaires (38.9%) as the most frequently employed measure of engagement. This trend likely coincides with the increase in online applications, facilitating access to users at a distance and at large scales. Interestingly, authors within this

updated sample spoke more often of clusters of 'user types' (Eveleigh et al. 2014; Ferguson and Clow 2015), patterns of engagement over time (Coffrin et al. 2014; Drutsa et al. 2015; Epstein et al. 2016; Lim et al. 2015), and of multiple levels of engagement (Mark et al. 2014; McGill et al. 2015).

The literature in the period 2014 to 2018 demonstrates many of the same patterns as prior to 2014, with an apparent increase in the percentage of research concerning online applications, community engagement and clustering of users and patterns of engagement in particular (keeping in mind the smaller sample size of this latter sample). Increased adoption of behaviour logging metrics underlines the importance of achieving and maintaining a broader conceptual grasp on engagement. Engagement research continues apace.

8 CONCLUSION

This article provides a grounding for the interpretation and measurement of engagement across HCI and Computer Science, which may allow us to fret less about what engagement 'is' and to instead focus on the value it provides. We have examined the theoretical grounding of definitions of engagement and located these interpretations within an HCI ecology of state, agent, and interaction. The conception of engagement is very often tied to measurement, and so we have also examined the choice of subjective and objective measures and motivations for their adoption. By individuating strategies for the design of engaging user experiences, we identify opportunities for employing the concept within new design projects. Finally, we have identified areas for future work, as well as recent trends across the engagement literature, including the increased use of behaviour logging.

ELECTRONIC SUPPLEMENT

The complete review corpora are available via electronic supplement.

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REFERENCES

Ernest Adams. 1999. Three problems for interactive storytellers. *Designer's Notebook Column, Gamasutra* 144 (1999). Retrieved on October 12, 2018 from https://www.gamasutra.com/view/feature/131821/the_designers_notebook_three_.php.

Ioannis Arapakis, Mounia Lalmas, and George Valkanas. 2014. Understanding within-content engagement through pattern analysis of mouse gestures. In *Proceedings of the 23rd ACM International Conference on Conference on Information and Knowledge Management*. ACM, 1439–1448.

Simon Attfield, Gabriella Kazai, Mounia Lalmas, and Benjamin Piwowarski. 2011. Towards a science of user engagement. In *Proceedings of the WSDM Workshop on User Modelling for Web Applications*.

Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers. 2005. Affect: From information to interaction. In *Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility*. ACM, 59–68.

Gordon Calleja. 2007. Digital games as designed experience: Reframing the concept of immersion (unpublished) .

Carleton Coffrin, Linda Corrin, Paula de Barba, and Gregor Kennedy. 2014. Visualizing patterns of student engagement and performance in MOOCs. In *Proceedings of the 4th International Conference on Learning Analytics and Knowledge*. ACM, 83–92.

Mauro José de Oliveira, Melby Karina Zuniga Huertas, and Zhibin Lin. 2016. Factors driving young users' engagement with Facebook: Evidence from Brazil. *Comput. Hum. Behav.* 54 (2016), 54–61.

Daniel C. Dennett. 1971. Intentional systems. *J. Philos.* 68, 4 (1971), 87–106.

Daniel C. Dennett. 1988. Quining qualia. *Consciousness in Modern Science* (1988).

Kevin Doherty and Gavin Doherty. 2018. The construal of experience in HCI: Understanding self-reports. *Int. J. Hum.-Comput. Stud.* 110 (2018), 63–74.

Alexey Drutsa, Gleb Gusev, and Pavel Serdyukov. 2015. Engagement periodicity in search engine usage: Analysis and its application to search quality evaluation. In *Proceedings of the 8th ACM International Conference on Web Search and Data Mining*. ACM, 27–36.

Daniel A. Epstein, Jennifer H. Kang, Laura R. Pina, James Fogarty, and Sean A. Munson. 2016. Reconsidering the device in the drawer: Lapses as a design opportunity in personal informatics. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 829–840.

Alexandra Eveleigh, Charlene Jennett, Ann Blandford, Philip Brohan, and Anna L. Cox. 2014. Designing for dabblers and deterring drop-outs in citizen science. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2985–2994.

Rebecca Ferguson and Doug Clow. 2015. Examining engagement: Analysing learner subpopulations in massive open online courses (MOOCs). In *Proceedings of the 5th International Conference on Learning Analytics and Knowledge*. ACM, 51–58.

Arlene Fink. 2013. *Conducting Research Literature Reviews: From the Internet to Paper*. Sage Publications.

William Fleeson. 2007. Situation-based contingencies underlying trait-content manifestation in behavior. *J. Pers.* 75, 4 (2007), 825–862.

Jennifer A. Fredricks, Phyllis C. Blumenfeld, and Alison H. Paris. 2004. School engagement: Potential of the concept, state of the evidence. *Rev. Educ. Res.* 74, 1 (2004), 59–109.

Erving Goffman et al. 1978. *The Presentation of Self in Everyday Life*. Harmondsworth.

Charles A. E. Goodhart. 1975. Problems of monetary management: The UK experience. In *Papers in Monetary Economics, Volume I*. Reserve Bank of Australia.

Jonathan Grix. 2010. *The Foundations of Research*. Palgrave Macmillan.

Mohammad Reza Habibi, Michel Laroche, and Marie-Odile Richard. 2014. The roles of brand community and community engagement in building brand trust on social media. *Comput. Hum. Behav.* 37 (2014), 152–161.

Juho Hamari, David J. Shernoff, Elizabeth Rowe, Brianno Coller, Jodi Asbell-Clarke, and Teon Edwards. 2016. Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Comput. Human Behav.* 54 (2016), 170–179.

Chris Hart. 2001. *Doing a Literature Search: A Comprehensive Guide for the Social Sciences*. Sage.

Kasper Hornbæk. 2006. Current practice in measuring usability: Challenges to usability studies and research. *Int. J. Hum.-Comput. Stud.* 64, 2 (2006), 79–102.

Eva Hudlicka. 2008. What are we modeling when we model emotion? In *Proceedings of the AAAI Spring Symposium: Emotion, Personality, and Social Behavior*. 52–59.

Christopher D. Hundhausen, Sarah A. Douglas, and John T. Stasko. 2002. A meta-study of software visualization effectiveness. *J. Vis. Lang. Comput.* 13, 3 (2002), 259–290.

Heekyoung Jung, Erik Stolterman, Will Ryan, Tonya Thompson, and Marty Siegel. 2008. Toward a framework for ecologies of artifacts: How are digital artifacts interconnected within a personal life? In *Proceedings of the 5th Nordic Conference on Human-computer Interaction: Building Bridges*. ACM, 201–210.

Song Jung and Sangwon Lee. 2016. Developing a model for continuous user engagement in social media. In *Proceedings of the 10th International Conference on Ubiquitous Information Management and Communication*. ACM, 19.

Avinash Kaushik. 2007. Engagement Is Not A Metric, It's An Excuse. Retrieved May 8, 2016 from http://www.kaushik.net/avinash/engagement-is-not-a-metric-its-an-excuse/.

Matthew A. Killingsworth and Daniel T. Gilbert. 2010. A wandering mind is an unhappy mind. *Science* 330, 6006 (2010), 932–932.

Barbara Kitchenham, O. Pearl Brereton, David Budgen, Mark Turner, John Bailey, and Stephen Linkman. 2009. Systematic literature reviews in software engineering–a systematic literature review. *Inf. Softw. Technol.* 51, 1 (2009), 7–15.

Alfred Korzybski. 1958. *Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics*. Institute of GS.

Brenda Laurel. 1991. Computers as theatre. 1991. *Addison-Wesley, New York, NY*.

Joon Soo Lim, YoungChan Hwang, Seyun Kim, and Frank A. Biocca. 2015. How social media engagement leads to sports channel loyalty: Mediating roles of social presence and channel commitment. *Comput. Hum. Behav.* 46 (2015), 158–167.

Gitte Lindgaard and Cathy Dudek. 2003. What is this evasive beast we call user satisfaction? *Interact. Comput.* 15, 3 (2003), 429–452.

Gloria Mark, Shamsi T. Iqbal, Mary Czerwinski, and Paul Johns. 2014. Bored mondays and focused afternoons: The rhythm of attention and online activity in the workplace. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 3025–3034.

John McCarthy and Peter Wright. 2004. *Technology as Experience*. MIT Press, Cambridge, MA.

Mark McGill, Daniel Boland, Roderick Murray-Smith, and Stephen Brewster. 2015. A dose of reality: Overcoming usability challenges in vr head-mounted displays. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2143–2152.

David Moher, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G. Altman. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann. Internal Med.* 151, 4 (2009), 264–269.

Rosalind W. Picard. 2000. *Affective Computing*. MIT Press.

Isabella Poggi. 2007. *Mind, Hands, Face and Body. A Goal and Belief View of Multimodal Communication*. Weidler.

Karl R. Popper. 1959. *The Logic of Scientific Discovery*. Hutchinson, London.

Chris Preist, Elaine Massung, and David Coyle. 2014. Competing or aiming to be average?: Normification as a means of engaging digital volunteers. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*. ACM, 1222–1233.

Whitney Quesenbury. 2002. The five dimensions of usability. *Content and Complexity: Information Design in Technical Communication*, Michael J. Albers and Mary Beth Mazur (Eds.). Routledge, 81–102.

Dimitrios Raptis, Jesper Kjeldskov, Mikael B. Skov, and Jeni Paay. 2014. What is a digital ecology?: Theoretical foundations and a unified definition. *Austr. J. Intell. Inf. Process. Syst.* 13, 4 (2014).

Soumya Ray, Sung S. Kim, and James G. Morris. 2014. The central role of engagement in online communities. *Inf. Syst. Res.* 25, 3 (2014), 528–546.

Horst W. J. Rittel and Melvin M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sci.* 4, 2 (1973), 155–169.

Yvonne Rogers. 2006. Moving on from Weiser's vision of calm computing: Engaging ubicomp experiences. In *Proceedings of the Annual Conference on Ubiquitous Computing (UbiComp'06)*. Springer, 404–421.

Natasha Dow Schüll. 2012. *Addiction by Design: Machine Gambling in Las Vegas*. Princeton University Press.

Herbert A. Simon. 1969. *The Sciences of the Artificial. Cambridge*. MIT Press Cambridge, MA.

Paul Thomas, Heather O'Brien, and Tom Rowlands. 2016. Measuring engagement with online forms. In *Proceedings of the 2016 ACM on Conference on Human Information Interaction and Retrieval*. ACM, 325–328.

David Zyngier. 2007. Listening to teachers–listening to students: Substantive conversations about resistance, empowerment and engagement. *Teach. Teach. Theory Pract.* 13, 4 (2007), 327–347.

David Zyngier. 2008. (Re) conceptualising student engagement: Doing education not doing time. *Teach. Teach. Educ.* 24, 7 (2008), 1765–1776.

REVIEW CORPUS REFERENCES

Mojtaba Khomami Abadi, Jacopo Staiano, Alessandro Cappelletti, Massimo Zancanaro, and Nicu Sebe. 2013. Multimodal engagement classification for affective cinema. In *Proceedings of the 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction*. IEEE, 411–416.

Alex Abreu, Gye Won Gho, and Daragh Byrne. 2013. Scatter!: A mobile non-parallel multiplayer exertion game. In *Proceedings of the 12th International Conference on Interaction Design and Children (IDC'13)*. ACM Press, 632.

Rieks Akker, Dennis Hofs, Hendri Hondorp, Harm Akker, Job Zwiers, and Anton Nijholt. 2009. Supporting engagement and floor control in hybrid meetings. In *Cross-Modal Analysis of Speech, Gestures, Gaze and Facial Expressions*. Vol. 5641. Springer, Berlin, 276–290.

Stylianos Asteriadis, Kostas Karpouzis, and Stefanos Kollias. 2009. Feature extraction and selection for inferring user engagement in an HCI environment. In *Proceedings of the 13th International Conference on Human-Computer Interaction. Part I: New Trends*, Vol. 5610. Springer, Berlin, 22–29.

Ron Baecker, Melanie Baran, Jeremy Birnholtz, Clarence Chan, Joe Laszlo, Kelly Rankin, Russ Schick, and Peter Wolf. 2006. Enhancing interactivity in webcasts with VoIP. In *Proceedings of the CHI'06 Extended Abstracts on Human Factors in Computing Systems (CHI EA'06)*. ACM Press, 235.

Ricardo Baeza-Yates and Mounia Lalmas. 2012. User engagement: The network effect matters! In *Proceedings of the 21st ACM International Conference on Information and Knowledge Management (CIKM'12)*. ACM Press, 1.

Rafael Ballagas, Thérèse E. Dugan, Glenda Revelle, Koichi Mori, Maria Sandberg, Janet Go, Emily Reardon, and Mirjana Spasojevic. 2013. Electric agents: Fostering sibling joint media engagement through interactive television and augmented reality. In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work (CSCW'13)*. ACM Press, 225.

Alex Barco, Jordi Albo-Canals, and Carles Garriga. 2014. Engagement based on a customization of an iPod-LEGO robot for a long-term interaction for an educational purpose. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction (HRI'14)*. ACM Press, 124–125.

Jeffrey Bardzell, Shaowen Bardzell, Tyler Pace, and Jeremi Karnell. 2008. Making user engagement visible: A multimodal strategy for interactive media experience research. In *Proceeding of the 26th annual CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI'08)*. ACM Press, 3663.

Anastasios (Tasos) Barkatsas, Katerina Kasimatis, and Vasilis Gialamas. 2009. Learning secondary mathematics with technology: Exploring the complex interrelationship between students' attitudes, engagement, gender and achievement. *Comput. Educ.* 52, 3 (Apr. 2009), 562–570.

Carole R. Beal, Lei Qu, and Hyokyeong Lee. 2006. Classifying learner engagement through integration of multiple data sources. In *Proceedings of the National Conference on Artificial Intelligence*. AAAI Press, 151–156.

Russell Beale and Chris Creed. 2009. Affective interaction: How emotional agents affect users. *Int. J. Hum.-Comput. Stud.* 67, 9 (Sept. 2009), 755–776.

Ashwin Belle, Rosalyn Hobson, and Kayvan Najarian. 2011. A physiological signal processing system for optimal engagement and attention detection. In *Proceedings of the 2011 IEEE International Conference on Bioinformatics and Biomedicine Workshops (BIBMW'11)*. IEEE, 555–561.

Sebastian Hurup Bevensee, Kasper Alexander Dahlsgaard Boisen, Mikael Peter Olsen, Henrik Schoenau-Fog, and Luis Emilio Bruni. 2012. Aporia—Exploring continuation desire in a game focused on environmental storytelling. In *Proceedings of the 5th International Conference on Interactive Storytelling*, Vol. 7648. Springer, Berlin, 42–47.

Nadia Bianchi-Berthouze, Whan Woong Kim, and Darshak Patel. 2007. Does body movement engage you more in digital game play? and why? In *Proceedings of the 2nd International Conference on Affective Computing and Intelligent Interaction (ACII'07)*, Vol. 4738. Springer, Berlin, 102–113.

Timothy Bickmore, Daniel Schulman, and Langxuan Yin. 2010. Maintaining engagement in long-term interventions with relational agents. *Appl. Artif. Intell.* 24, 6 (Jul. 2010), 648–666.

Timothy W. Bickmore, Sunny Consolvo, and Stephen S. Intille. 2009. Engagement by design. In *Proceedings of the 27th International Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA'09)*. ACM Press, 4807.

Cezary Biele, Agata Kopacz, and Krzysztof Krejtz. 2013. Shall we care about the user's feelings?: Influence of affect and engagement on visual attention. In *Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation (MIDI'13)*. ACM Press, 1.

Stacey Birkett, Adam Galpin, Simon Cassidy, Lynne Marrow, and Sarah Norgate. 2011. How revealing are eye-movements for understanding web engagement in young children. In *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA'11*). ACM Press, 2251.

Jeremy Birnholtz, Jeff Hancock, and Daniela Retelny. 2013. Tweeting for class: Co-construction as a means for engaging students in lectures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'13)*. ACM Press, 797.

Robert Bixler and Sidney D'Mello. 2013. Detecting boredom and engagement during writing with keystroke analysis, task appraisals, and stable traits. In *Proceedings of the 2013 International Conference on Intelligent User Interfaces (IUI'13)*. ACM Press, 225.

Benjamin Blankertz, Michael Tangermann, Carmen Vidaurre, Siamac Fazli, Claudia Sannelli, Stefan Haufe, Cecilia Maeder, Lenny Ramsey, Irene Sturm, Gabriel Curio, et al. 2010. The Berlin brain–computer interface: Non-medical uses of BCI technology. *Front. Neurosci.* 4 (2010).

Lorena Blasco-Arcas, Isabel Buil, Blanca Hernández-Ortega, and F. Javier Sese. 2013. Using clickers in class. The role of interactivity, active collaborative learning and engagement in learning performance. *Comput. Educ.* 62 (Mar. 2013), 102–110.

Dan Bohus and Eric Horvitz. 2009a. Dialog in the open world: Platform and applications. In *Proceedings of the 2009 International Conference on Multimodal Interfaces (ICMI-MLMI'09)*. ACM Press, 31.

Dan Bohus and Eric Horvitz. 2009b. Learning to predict engagement with a spoken dialog system in open-world settings. In *Proceedings of the 10th Annual Meeting of the Special Interest Group on Discourse and Dialogue (SIGDIAL'09)*. Association for Computational Linguistics, 244–252.

Dan Bohus and Eric Horvitz. 2009c. Models for multiparty engagement in open-world dialog. In *Proceedings of the 10th Annual Meeting of the Special Interest Group on Discourse and Dialogue (SIGDIAL'09)*. Association for Computational Linguistics, 225–234.

Francesca Bonin, Ronald Bock, and Nick Campbell. 2012. How do we react to context? Annotation of individual and group engagement in a video corpus. In *Proceedings of the 2012 International Conference on Privacy, Security, Risk and Trust and 2012 International Conference on Social Computing*. IEEE, 899–903.

Hara Bouta and Symeon Retalis. 2013. Enhancing primary school children collaborative learning experiences in maths via a 3D virtual environment. *Educ. Inf. Technol.* 18, 4 (May 2013), 571–596.

Elizabeth A. Boyle, Thomas M. Connolly, Thomas Hainey, and James M. Boyle. 2012. Engagement in digital entertainment games: A systematic review. *Comput. Hum. Behav.* 28, 3 (May 2012), 771–780.

Jeanne H. Brockmyer, Christine M. Fox, Kathleen A. Curtiss, Evan McBroom, Kimberly M. Burkhart, and Jacquelyn N. Pidruzny. 2009. The development of the game engagement questionnaire: A measure of engagement in video game-playing. *J. Exp. Soc. Psychol.* 45, 4 (2009), 624–634.

Eva Petersson Brooks. 2013. Ludic engagement designs: Creating spaces for playful learning. In *Proceedings of the 7th International Conference on Universal Access in Human-Computer Interaction (UAHCI'13)*, Vol. 8011. Springer, Berlin, 241–249.

Emily Brown and Paul Cairns. 2004. A grounded investigation of game immersion. In *Extended Abstracts of the 2004 Conference on Human Factors and Computing Systems (CHI'04)*. ACM Press, 1297.

Nick Bryan-Kinns. 2013. Mutual engagement and collocation with shared representations. *Int. J. Hum.-Comput. Stud.* 71, 1 (Jan. 2013), 76–90.

Agnese Caglio and Jacob Buur. 2012. Creating engagement with old research videos. In *Proceedings of the 2012 International Symposium on Pervasive Displays (PerDis'12)*. ACM Press, 1–6.

Hua Cai and Yingzi Lin. 2012. Coordinating cognitive assistance with cognitive engagement control approaches in human-machine collaboration. *IEEE Trans. Syst. Man Cybernet. A* 42, 2 (Mar. 2012), 286–294.

Tara Carrigy, Katsiaryna Naliuka, Natasa Paterson, and Mads Haahr. 2010. Design and evaluation of player experience of a location-based mobile game. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction Extending Boundaries (NordiCHI'10)*. ACM Press, 92.

Ginevra Castellano, André Pereira, Iolanda Leite, Ana Paiva, and Peter W. McOwan. 2009. Detecting user engagement with a robot companion using task and social interaction-based features. In *Proceedings of the 2009 International Conference on Multimodal Interfaces (ICMI-MLMI'09)*. ACM Press, 119.

Mark Chen, Beth E. Kolko, Elisabeth Cuddihy, and Eliana Medina. 2011. Modeling but NOT measuring engagement in computer games. In *Proceedings of the 7th International Conference on Games + Learning + Society*. ETC Press, 55–63.

Vinay Chilukuri and Bipin Indurkhya. 2011. An algorithm to generate engaging narratives through non-linearity. In *Proceedings of the 22nd ACM Conference on Hypertext and Hypermedia (HT'11)*. ACM Press, 291.

Ahyoung Choi, Celso De Melo, Woontack Woo, and Jonathan Gratch. 2012. Affective engagement to emotional facial expressions of embodied social agents in a decision-making game. *Comput. Anim. Virt. Worlds* 23, 3–4 (May 2012), 331–342.

Jung Ju Choi, Yunkyung Kim, and Sonya S. Kwak. 2014. Are you embarrassed?: The impact of robot types on emotional engagement with a robot. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot interaction (HRI'14)*. ACM Press, 138–139.

Chun-Juei Chou and Chris Conley. 2011. Investigating users' interaction with physical products applying qualitative and quantitative methods. In *Proceedings of the 2nd International Conference on Human Centered Design*. Springer-Verlag, 3–12.

Hsin-Kai Chou, I-Chun Lin, Lin-Chung Woung, and Ming-Tsu Tsai. 2012. Engagement in E-learning opportunities: An empirical study on patient education using expectation confirmation theory.*J. Med. Syst.* 36, 3 (Jun. 2012), 1697–706.

Elizabeth F. Churchill. 2010. Enticing engagement. *Interactions* 17, 3 (May 2010), 82.

Mihaela Cocea and Stephan Weibelzahl. 2007. Cross-system validation of engagement prediction from log files. *Creating New Learning Experiences on a Global Scale*, Erik Duval, Ralf Klamma, and Martin Wolpers (Eds.). Springer, Berlin Heidelberg, 14–25.

Martin Colbert and Angela Boodoo. 2011. Does 'Letting Go of the Words' increase engagement: A traffic study. In *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA'11)*. ACM Press, 655.

Luca Colombo and Monica Landoni. 2011. Towards an engaging e-reading experience. In *Proceedings of the 4th ACM Workshop on Online Books, Complementary Social Media and Crowdsourcing (BooksOnline'11*). ACM Press, 61.

Thomas M. Connolly, Elizabeth A. Boyle, Ewan MacArthur, Thomas Hainey, and James M. Boyle. 2012. A systematic literature review of empirical evidence on computer games and serious games. *Comput. Educ.* 59, 2 (Sept. 2012), 661–686.

Lee J. Corrigan, Christina Basedow, Dennis Küster, Arvid Kappas, Christopher Peters, and Ginevra Castellano. 2014. Mixing implicit and explicit probes: Finding a ground truth for engagement in social human-robot interactions. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction (HRI'14)*. ACM Press, 140–141.

Lee J. Corrigan, Christopher Peters, and Ginevra Castellano. 2013. Identifying task engagement: Towards personalised interactions with educational robots. In *Proceedings of the 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction*. IEEE, 655–658.

Ben Cowley, Darryl Charles, Michaela Black, and Ray Hickey. 2008. Toward an understanding of flow in video games. *Comput. Entertain.* 6, 2 (Jul. 2008), 1.

Peter Dalsgaard, Christian Dindler, and Kim Halskov. 2011. Understanding the dynamics of engaging interaction in public spaces. In *Proceedings of the 13th IFIP TC 13 International Conference on Human-computer Interaction (INTERACT'11)*. Springer-Verlag, 212–229.

Anirban Dasgupta, Kunal Punera, Justin M. Rao, and Xuanhui Wang. 2012. Impact of spam exposure on user engagement. In *Proceedings of the 21st USENIX Conference on Security Symposium (Security'12)*. USENIX Association, 3.

Chris H. J. Davies. 2002. Student engagement with simulations: A case study. *Comput. Educ.* 39, 3 (Nov. 2002), 271–282.

Kristine Deray and Simeon Simoff. 2012. Framing interaction through engagement in interactive open ended environments. In *Proceedings of the 16th International Conference on Information Visualisation*. IEEE, 534–539.

Christian Dindler, Ole Sejer Iversen, and Peter Gall Krogh. 2011. Engagement through mixed modalities. *Interactions* 18, 4 (Jul. 2011), 34.

Sidney D'Mello, Patrick Hays, Claire Williams, Whitney Cade, Jennifer Brown, and Andrew Olney. 2010. Collaborative lecturing by human and computer tutors. In *Proceedings of the 10th International Conference on Intelligent Tutoring Systems (ITS'10)*, Vol. 6095. Springer, Berlin, 178–187.

Florin Dobrian, Asad Awan, Dilip Joseph, Aditya Ganjam, Jibin Zhan, Vyas Sekar, Ion Stoica, and Hui Zhang. 2013. Understanding the impact of video quality on user engagement. *Commun. ACM* 56, 3 (Mar. 2013), 91.

Adrián Domínguez, Joseba Saenz-de Navarrete, Luis De-Marcos, Luis Fernández-Sanz, Carmen Pagés, and José-Javier Martínez-Herráiz. 2013. Gamifying learning experiences: Practical implications and outcomes. *Comput. Educ.* 63 (Apr. 2013), 380–392.

Claire Dormann, Pippin Barr, and Robert Biddle. 2006. Humour theory and videogames: Laughter in the slaughter. In *Proceedings of the 2006 ACM SIGGRAPH Symposium on Videogames (Sandbox'06)*. ACM Press, 95–98.

Yellowlees Douglas and Andrew Hargadon. 2000. The pleasure principle: Immersion, engagement, flow. In *Proceedings of the 11th ACM on Hypertext and hypermedia (HYPERTEXT'00)*. ACM Press, 153–160.

Steven Dow. 2007. User engagement in physically embodied narrative experiences. In *Proceedings of the 6th ACM SIGCHI Conference on Creativity & Cognition (C&C'07)*. ACM Press, 280.

Steven Dow, Manish Mehta, Ellie Harmon, Blair MacIntyre, and Michael Mateas. 2007. Presence and engagement in an interactive drama. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'07)*. ACM Press, 1475.

Georges Dupret and Mounia Lalmas. 2013. Absence time and user engagement: Evaluating ranking functions. In *Proceedings of the 6th ACM International Conference on Web Search and Data Mining (WSDM'13)*. ACM Press, 173.

Wade Fagen and Samuel Kamin. 2013. Measuring increased engagement using tablet PCs in a code review class. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE'13)*. ACM Press, 465.

Stephen H. Fairclough, Kiel Gilleade, Katie C. Ewing, and Jenna Roberts. 2013. Capturing user engagement via psychophysiology: Measures and mechanisms for biocybernetic adaptation. *Int. J. Auton. Adapt. Commun. Syst.* 6, 1 (Dec. 2013), 63.

Shelly Farnham, David Keyes, Vicky Yuki, and Chris Tugwell. 2012. Puget sound off: Fostering youth civic engagement through citizen journalism. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work (CSCW'12)*. ACM Press, 285.

Alessandro Febretti and Franca Garzotto. 2009. Usability, playability, and long-term engagement in computer games. In *Proceedings of the 27th International Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA'09)*. ACM Press, 4063.

Joel E. Fischer and Steve Benford. 2009. Inferring player engagement in a pervasive experience. In *Proceedings of the 27th International Conference on Human Factors in Computing Systems (CHI'09)*. ACM Press, 1903.

James Fogarty, Andrew J. Ko, Htet Htet Aung, Elspeth Golden, Karen P. Tang, and Scott E. Hudson. 2005. Examining task engagement in sensor-based statistical models of human interruptibility. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'05)*. ACM Press, 331.

Mary Ellen Foster, Andre Gaschler, and Manuel Giuliani. 2013. How can I help you?: Comparing engagement classification strategies for a robot bartender. In *Proceedings of the 15th ACM on International Conference on Multimodal Interaction (ICMI'13)*. ACM Press, 255–262.

Jill Freyne, Michal Jacovi, Ido Guy, and Werner Geyer. 2009. Increasing engagement through early recommender intervention. In *Proceedings of the 3rd ACM Conference on Recommender Systems (RecSys'09)*. ACM Press, 85.

Federico Cirett Galán and Carole R. Beal. 2012. EEG estimates of engagement and cognitive workload predict math problem solving outcomes. In *Proceedings of the 20th International Conference on User Modeling, Adaptation, and Personalization*, Vol. 7379. Springer, Berlin, 51–62.

Merve Gençer, Gökhan Bilgin, Özgür Zan, and Tansel VoyvodaoÄlu. 2013. A new framework for increasing user engagement in mobile applications using machine learning techniques. In *Proceedings of the International Conference of Design, User Experience, and Usability*. Springer, 651–659.

James Glasnapp and Oliver Brdiczka. 2009. A human-centered model for detecting technology engagement. In *Proceedings of the 13th International Conference on Human-Computer Interaction. Part III: Ubiquitous and Intelligent Interaction*, Vol. 5612. Springer, Berlin, 621–630.

Benjamin S. Goldberg, Robert A. Sottilare, Keith W. Brawner, and Heather K. Holden. 2011. Predicting learner engagement during well-defined and Ill-defined computer-based intercultural interactions. In *Proceedings of the 4th International Conference on Affective Computing and Intelligent Interaction—Volume Part I*. Springer-Verlag, 538–547.

Douglas Grimes, Mark Warschauer, Tara Hutchinson, and Falko Kuester. 2005. Computer graphics instruction in VizClass. *J. Educ. Resourc. Comput.* 5, 4 (Dec. 2005), 1–12.

Sofiane Gueddana and Nicolas Roussel. 2006. Pêle-Mêle, a video communication system supporting a variable degree of engagement. In *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work (CSCW'06)*. ACM Press, 423.

Hayrettin Gürkök, Gido Hakvoort, and Mannes Poel. 2011. Evaluating user experience in a selection based brain-computer interface game: A comparative study. In *Proceedings of the 10th International Conference on Entertainment Computing*, Vol. 6972. Springer, Berlin, 77–88.

Lynne Hall, Sarah Woods, Ruth Aylett, Lynne Newall, and Ana Paiva. 2005. Achieving empathic engagement through affective interaction with synthetic characters. In *Proceedings of the First International Conference on Affective Computing and Intelligent Interaction (ACII'05)*, Vol. 3784. Springer, Berlin, 731–738.

Stuart Hansen and Erica Eddy. 2007. Engagement and frustration in programming projects. *ACM SIGCSE Bull.* 39, 1 (Mar. 2007), 271.

Jennefer Hart, Alistair Sutcliffe, and Antonella De Angeli. 2012. Using affect to evaluate user engagement. In *Proceedings of the 2012 ACM Annual Conference Extended Abstracts on Human Factors in Computing Systems Extended Abstracts (CHIEA '12)*. ACM Press, 1811.

Casper Harteveld, Eleonore ten Thij, and Marinka Copier. 2011. Design for engaging experience and social interaction. *Simul. Gam.* 42, 5 (Nov. 2011), 590–595.

Patrick Hennig, Philipp Berger, Christoph Meinel, Maria Graber, Jens Hildebrandt, Stefan Lehmann, and Cathleen Ramson. 2013. Tracking visitor engagement in the blogosphere for leveraging rankings. In *Proceedings of the 2013 International Conference on Social Computing*. IEEE, 365–372.

J. M. Houtkamp, A. Toet, and F. A. Bos. 2012. Task-relevant sound and user experience in computer-mediated firefighter training. *Simul. Gam.* 43, 6 (May 2012), 778–802.

Paul Jen-Hwa Hu and Wendy Hui. 2012. Examining the role of learning engagement in technology-mediated learning and its effects on learning effectiveness and satisfaction. *Decis. Support Syst.* 53, 4 (Nov. 2012), 782–792.

Jessica Hullman, Eytan Adar, and Priti Shah. 2011. Benefitting InfoVis with visual difficulties. *IEEE Trans. Vis. Comput. Graph.* 17, 12 (Dec. 2011), 2213–22.

Mark I. Hwang and Ron G. Thorn. 1999. The effect of user engagement on system success: A meta-analytical integration of research findings. *Inf. Manage.* 35, 4 (Apr. 1999), 229–236.

Ioanna Iacovides. 2009. Exploring the link between player involvement and learning within digital games. In *Proceedings of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology*. British Computer Society, 29–34.

Ryo Ishii and Yukiko I. Nakano. 2008. Estimating user's conversational engagement based on gaze behaviors. In *Proceedings of the 8th International Conference on Intelligent Virtual Agents*, Vol. 5208. Springer, Berlin, 200–207.

Ryo Ishii and Yukiko I. Nakano. 2010. An empirical study of eye-gaze behaviors: Towards the estimation of conversational engagement in human-agent communication. In *Proceedings of the 2010 Workshop on Eye Gaze in Intelligent Human Machine Interaction (EGIHMI'10)*. ACM Press, 33–40.

Carolina Islas Sedano, Verona Leendertz, Mikko Vinni, Erkki Sutinen, and Suria Ellis. 2013. Hypercontextualized learning games: Fantasy, motivation, and engagement in reality. *Simul. Gam.* 44, 6 (Dec. 2013), 821–845.

Essi Isohanni and Maria Knobelsdorf. 2011. Students' long-term engagement with the visualization tool VIP. In *Proceedings of the 11th Koli Calling International Conference on Computing Education Research (Koli Calling'11)*. ACM Press, 33.

Giulio Jacucci, Ann Morrison, Gabriela T. Richard, Jari Kleimola, Peter Peltonen, Lorenza Parisi, and Toni Laitinen. 2010. Worlds of information: Designing for engagement at a public multi-touch display. In *Proceedings of the 28th International Conference on Human Factors in Computing Systems (CHI'10)*. ACM Press, 2267.

Alejandro Jaimes, Mounia Lalmas, and Yana Volkovich. 2011a. First international workshop on social media engagement (SoME 2011). In *Proceedings of the 20th International Conference companion on World Wide Web (WWW'11)*. ACM Press, 309.

Alejandro Jaimes, Mounia Lalmas, and Yana Volkovich. 2011b. First international workshop on social media engagement (SoME 2011) (report). *ACM SIGIR Forum* 45, 1 (May 2011), 56.

Leon A. Kappelman. 1995. Measuring user involvement: A diffusion of innovation perspective. *ACM SIGMIS Database* 26, 2–3 (May 1995), 65–86.

Ville Karavirta and Ari Korhonen. 2006. Automatic tutoring question generation during algorithm simulation. In *Proceedings of the 6th Baltic Sea Conference on Computing Education Research (Koli Calling'06)*. ACM Press, 95.

B. Joon Kim and Stephen W. Kleinschmit. 2012. A logistic multilevel model for civic engagement and community group impact in the digital age. In *Proceedings of the 6th International Conference on Theory and Practice of Electronic Governance (ICEGOV'12)*. ACM Press, 34.

Young Hoon Kim, Dan J. Kim, and Kathy Wachter. 2013. A study of mobile user engagement (MoEN): Engagement motivations, perceived value, satisfaction, and continued engagement intention. *Decis. Support Syst.* 56 (Dec. 2013), 361–370.

Samuel O. King and Carol L. Robinson. 2009. 'Pretty Lights' and maths! Increasing student engagement and enhancing learning through the use of electronic voting systems. *Comput. Educ.* 53, 1 (Aug. 2009), 189–199.

Ben Kirman, Shaun Lawson, Conor Linehan, Francesco Martino, Luciano Gamberini, and Andrea Gaggioli. 2010. Improving social game engagement on facebook through enhanced socio-contextual information. In *Proceedings of the 28th International Conference on Human Factors in Computing Systems (CHI'10)*. ACM Press, 1753.

Michel Klein and Rianne Van Lambalgen. 2011. Design of an optimal automation system: Finding a balance between a human's task engagement and exhaustion. In *Proceedings of the 24th International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems Conference on Modern Approaches in Applied Intelligence,Volume Part II*. Springer-Verlag, 98–108.

Natalia Kucirkova, David Messer, Kieron Sheehy, and Carmen Fernández Panadero. 2014. Children's engagement with educational iPad apps: Insights from a Spanish classroom. *Comput. Educ.* 71 (Feb. 2014), 175–184.

Stacey Kuznetsov, Will Harrigan-Anderson, Haakon Faste, Scott E. Hudson, and Eric Paulos. 2013. Community engagements with living sensing systems. In *Proceedings of the 9th ACM Conference on Creativity & Cognition (C&C'13)*. ACM Press, 213.

Chih-Hui Lai. 2014. An integrated approach to untangling mediated connectedness with online and mobile media. *Comput. Hum. Behav.* 31 (Feb. 2014), 20–26.

K. K. Lamberty. 2004. Sustaining student engagement with a constructionist design tool for craft and math. In *Proceeding of the 2004 Conference on Interaction Design and Children Building a Community (IDC'04)*. ACM Press, 165–166.

Celine Latulipe, Erin A. Carroll, and Danielle Lottridge. 2011. Love, hate, arousal and engagement: Exploring audience responses to performing arts. In *Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems (CHI'11)*. ACM Press, 1845.

Raymond S. T. Lee, James N. K. Liu, Karo S. Y. Yeung, Alan H. L. Sin, and Dennis T. F. Shum. 2009. Agent-based web content engagement time (WCET) analyzer on e-publication system. In *Proceedings of the 2009 9th International Conference on Intelligent Systems Design and Applications*. IEEE, 67–72.

Scott LeeTiernan and Jonathan Grudin. 2003. Supporting engagement in asynchronous education. In *Extended Abstracts on Human Factors in Computing Systems (CHI'03)*. ACM Press, 888.

Janette Lehmann, Mounia Lalmas, Ricardo Baeza-Yates, and Elad Yom-Tov. 2013a. Networked user engagement. In *Proceedings of the 1st Workshop on User Engagement Optimization (UEO'13)*. ACM Press, 7–10.

Janette Lehmann, Mounia Lalmas, Georges Dupret, and Ricardo Baeza-Yates. 2013b. Online multitasking and user engagement. In *Proceedings of the 22nd ACM International Conference on Conference on Information & Knowledge Management (CIKM'13)*. ACM Press, 519–528.

Janette Lehmann, Mounia Lalmas, Elad Yom-Tov, and Georges Dupret. 2012. Models of user engagement. In *Proceedings of the 20th International Conference on User Modeling, Adaptation, and Personalization (UMAP'12)*, Vol. 7379. Springer, Berlin, 164–175.

Gilly Leshed, Theresa Velden, Oya Rieger, Blazej Kot, and Phoebe Sengers. 2008. In-car gps navigation: Engagement with and disengagement from the environment. In *Proceeding of the 26th Annual CHI Conference on Human Factors in Computing Systems (CHI'08)*. ACM Press, 1675.

Aleck C. H. Lin, Walter D. Fernandez, and Shirley Gregor. 2012. Understanding web enjoyment experiences and informal learning: A study in a museum context. *Decis. Support Syst.* 53, 4 (Nov. 2012), 846–858.

Siân E. Lindley, James Le Couteur, and Nadia L. Berthouze. 2008. Stirring up experience through movement in game play: Effects on engagement and social behaviour. In *Proceeding of the 26th Annual CHI Conference on Human Factors in Computing Systems (CHI'08)*. ACM Press, 511.

Micah Linnemeier, Yi-Ying Lin, Gierad Laput, and Ramachandra Vijjapurapu. 2012. StoryCubes: Connecting elders in independent living through storytelling. In *Proceedings of the 2012 ACM Annual Conference Extended Abstracts on Human Factors in Computing Systems Extended Abstracts (CHI EA'12)*. ACM Press, 1321.

Yefeng Liu, Todorka Alexandrova, and Tatsuo Nakajima. 2011. Gamifying intelligent environments. In *Proceedings of the 2011 International ACM Workshop on Ubiquitous Meta User Interfaces (Ubi-MUI'11)*. ACM Press, 7.

Derek Lomas, John Stamper, Ryan Muller, Kishan Patel, and Kenneth R. Koedinger. 2012. The effects of adaptive sequencing algorithms on player engagement within an online game. In *Proceedings of the 11th International Conference on Intelligent Tutoring Systems (ITS'12)*, Vol. 7315. Springer, Berlin, 588–590.

Luca Longo. 2011. Human-computer interaction and human mental workload: Assessing cognitive engagement in the world wide web. In *Proceedings of the IFIP Conference on Human-Computer Interaction*. Springer-Verlag, 402–405.

Bride Mallon and Brian Webb. 2000. Structure, causality, visibility and interaction: Propositions for evaluating engagement in narrative multimedia. *Int. J. Hum.-Comput. Stud.* 53, 2 (Aug. 2000), 269–287.

Tim Marsh, Michael Nitsche, Wei Liu, Peichi Chung, Jay D. Bolter, and Adrian D. Cheok. 2008. Film informing design for contemplative gameplay. In *Proceedings of the 2008 ACM SIGGRAPH Symposium on Video Games (Sandbox'08)*. ACM Press, 99.

Francesco Martino, Roberto Baù, Anna Spagnolli, and Luciano Gamberini. 2009. Presence in the age of social networks: Augmenting mediated environments with feedback on group activity. *Virt. Real.* 13, 3 (Jul. 2009), 183–194.

Lori McCay-Peet, Mounia Lalmas, and Vidhya Navalpakkam. 2012. On saliency, affect and focused attention. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems (CHI'12)*. ACM Press, 541.

Elisabeth McClure. 2013. Infant emotional engagement in video mediated interactions. In *Proceedings of the 12th International Conference on Interaction Design and Children (IDC'13)*. ACM Press, 655.

Olivia Metcalf and Kristen Pammer. 2011. Attentional bias in excessive massively multiplayer online role-playing gamers using a modified Stroop task. *Comput. Hum. Behav.* 27, 5 (Sept. 2011), 1942–1947.

Niko Myller, Roman Bednarik, Erkki Sutinen, and Mordechai Ben-Ari. 2009. Extending the engagement taxonomy: Software visualization and collaborative learning. *ACM Trans. Comput. Educ.* 9, 1 (Mar. 2009), 1–27.

Yukiko Nakano and Yuji Yamaoka. 2009. Information state based multimodal dialogue management: Estimating conversational engagement from gaze information. In *Proceedings of the 9th International Conference on Intelligent Virtual Agents (IVA'09)*, Vol. 5773. Springer, Berlin, 531–532.

Thomas L. Naps, Susan Rodger, J. Ángel Velázquez-Iturbide, Guido Rößling, Vicki Almstrum, Wanda Dann, Rudolf Fleischer, Chris Hundhausen, Ari Korhonen, Lauri Malmi, and Myles McNally. 2002. Exploring the role of visualization and engagement in computer science education. *ACM SIGCSE Bull.* 35, 2 (Jun. 2002), 131.

Surya Nepal, Wanita Sherchan, and Cecile Paris. 2012. Building trust communities using social trust. *Adv. User Model.* 7138 (Jul. 2012), 243–255.

Mark Notess. 2008. The e-Learning Rules of Engagement. *eLearn* 2008, 11 (Nov. 2008), 2.

Heather L. O'Brien and Elaine G. Toms. 2008. What is user engagement? A conceptual framework for defining user engagement with technology. *J. Am. Soc. Inf. Sci. Technol.* 59, 6 (Apr. 2008), 938–955.

Heather L. O'Brien and Elaine G. Toms. 2010a. Is there a universal instrument for measuring interactive information retrieval? In *Proceeding of the 3rd Symposium on Information Interaction in Context (IIiX'10)*. ACM Press, 335.

Heather L. O'Brien and Elaine G. Toms. 2010b. The development and evaluation of a survey to measure user engagement. *J. Am. Soc. Inf. Sci. Technol.* 61, 1 (Jan. 2010), 50–69.

Heather L. O'Brien and Elaine G. Toms. 2013. Examining the generalizability of the user engagement scale (UES) in exploratory search. *Inf. Process. Manage.* 49, 5 (Sept. 2013), 1092–1107.

Catharine Oertel. 2013. Towards developing a model for group involvement and individual engagement. In *Proceedings of the 15th ACM on International Conference on Multimodal Interaction (ICMI'13)*. ACM Press, 349–352.

Catharine Oertel and Giampiero Salvi. 2013. A gaze-based method for relating group involvement to individual engagement in multimodal multiparty dialogue. In *Proceedings of the 15th ACM on International Conference on Multimodal Interaction (ICMI'13)*. ACM Press, 99–106.

Kimmo Oksanen. 2013. Subjective experience and sociability in a collaborative serious game. *Simul. Gam.* 44, 6 (Dec. 2013), 767–793.

Ryota Ooko, Ryo Ishii, and Yukiko I. Nakano. 2011. Estimating a user's conversational engagement based on head pose information. In *Proceedings of the 10th International Conference on Intelligent Virtual Agents (IVA'11)*. Springer-Verlag, 262–268.

Sharon Oviatt, Colin Swindells, and Alex Arthur. 2008. Implicit user-adaptive system engagement in speech and pen interfaces. In *Proceedings of the 26th Annual CHI Conference on Human Factors in Computing Systems (CHI'08)*. ACM Press, 969.

Hun Myoung Park. 2006. The impacts of digital government on civic engagement: A typology of information technology use. In *Proceedings of the 2006 National Conference on Digital Government Research (dg.o'06)*. ACM Press, 440.

Jon Pearce and Sofia Pardo. 2008. To search or to explore – that is the question: A study in mindful engagement. In *Proceedings of the 20th Australasian Conference on Computer-Human Interaction Designing for Habitus and Habitat (OZCHI'08)*. ACM Press, 251.

Christopher Peters, Ginevra Castellano, and Sara de Freitas. 2009. An exploration of user engagement in HCI. In *Proceedings of the International Workshop on Affective-Aware Virtual Agents and Social Robots (AFFINE'09)*. ACM Press, 1–3.

Henning Pohl and Roderick Murray-Smith. 2013. Focused and casual interactions: Allowing users to vary their level of engagement. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'13)*. ACM Press, 2223.

Charles Rich, Brett Ponsleur, Aaron Holroyd, and Candace L. Sidner. 2010. Recognizing engagement in human-robot interaction. In *Proceedings of the 5th ACM/IEEE International Conference on Human-robot Interaction*. IEEE Press, 375–382.

Marco C. Rozendaal, David V. Keyson, and Huib de Ridder. 2007. Product behavior and appearance effects on experienced engagement during experiential and goal-directed tasks. In *Proceedings of the 2007 Conference on Designing Pleasurable Products and Interfaces (DPPI'07)*. ACM Press, 181.

Marco C. Rozendaal, David V. Keyson, and Huib Ridder. 2008. Product features and task effects on experienced richness, control and engagement in voicemail browsing. *Pers. Ubiq. Comput.* 13, 5 (Jun. 2008), 343–354.

Marco C. Rozendaal, David V. Keyson, Huib Ridder, and Peter O. Craig. 2009. Game feature and expertise effects on experienced richness, control and engagement in game play. *AI Soc.* 24, 2 (Mar. 2009), 123–133.

Jyotirmay Sanghvi, Ginevra Castellano, Iolanda Leite, André Pereira, Peter W. McOwan, and Ana Paiva. 2011. Automatic analysis of affective postures and body motion to detect engagement with a game companion. In *Proceedings of the 6th International Conference on Human-robot Interaction (HRI'11)*. ACM Press, 305.

Henrik Schoenau-Fog. 2011. Hooked! - Evaluating engagement as continuation desire in interactive narratives. In *Proceedings of the 4th International Conference on Interactive Digital Storytelling (ICIDS'11)*, Vol. 7069. Springer, Berlin, 219–230.

Henrik Schoenau-Fog, Alexander Birke, and Lars Reng. 2012. Evaluation of continuation desire as an iterative game development method. In *Proceeding of the 16th International Academic MindTrek Conference (MindTrek'12)*. ACM Press, 241.

Ellen Lisette Schuurink, Joske Houtkamp, and Alexander Toet. 2008. Engagement and EMG in serious gaming: Experimenting with sound and dynamics in the levee patroller training game. In *Proceedings of the 2nd International Conference on Fun and Games*, Vol. 5294. Springer, Berlin, 139–149.

May-li Seah and Paul Cairns. 2008. From immersion to addiction in videogames. In *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction (BCS-HCI'08)*, Volume 1. British Computer Society, 55–63.

Kathy Seddon, Nigel C. Skinner, and Keith C. Postlethwaite. 2008. Creating a model to examine motivation for sustained engagement in online communities. *Educ. Inf. Technol.* 13, 1 (Aug. 2008), 17–34.

Soonhwa Seok and Boaventura DaCosta. 2012. The world's most intense online gaming culture: Addiction and high-engagement prevalence rates among South Korean adolescents and young adults. *Comput. Hum. Behav.* 28, 6 (Nov. 2012), 2143–2151.

C. L. Sidner and M. Dzikovska. 2002. Human-robot interaction: Engagement between humans and robots for hosting activities. In *Proceedings of the 4th IEEE International Conference on Multimodal Interfaces*. IEEE Comput. Soc., 123–128.

Candace L. Sidner, Cory D. Kidd, Christopher Lee, and Neal Lesh. 2004. Where to look: A study of human-robot engagement. In *Proceedings of the 9th International Conference on Intelligent User Interface (IUI'04)*. ACM Press, 78.

Candace L. Sidner, Christopher Lee, Cory D. Kidd, Neal Lesh, and Charles Rich. 2005. Explorations in engagement for humans and robots. *Artif. Intell.* 166, 1-2 (Aug. 2005), 140–164.

Bradley A. Singletary and Thad E. Starner. 2001. Learning visual models of social engagement. In *Proceedings of the IEEE ICCV Workshop on Recognition, Analysis, and Tracking of Faces and Gestures in Real-Time Systems, 2001*. IEEE Computer Society, 141.

Stephen Snow, Laurie Buys, Paul Roe, and Margot Brereton. 2013. Curiosity to cupboard: Self reported disengagement with energy use feedback over time. In *Proceedings of the 25th Australian Computer-Human Interaction Conference on Augmentation, Application, Innovation, Collaboration (OzCHI'13)*. ACM Press, 245–254.

Social Computing Research Group. 2005. Understanding computer mediated social experience: Implications for CSCL. In *Proceedings of the 2005 Conference on Computer Support for Collaborative Learning: Learning 2005: The Next 10 years!* International Society of the Learning Sciences, 617–621.

Yang Song, Xiaolin Shi, and Xin Fu. 2013. Evaluating and predicting user engagement change with degraded search relevance. In *Proceedings of the 22nd International Conference on World Wide Web*. International World Wide Web Conferences Steering Committee, 1213–1224.

Itana Stiubiener, Regina M. Silveira, Reinaldo Matushima, Graca Bressan, and Wilson V. Ruggiero. 2012. Evaluating the effectiveness of the use of teaching materials in video format in distance learning environments. In *Proceedings of the 2012 Frontiers in Education Conference Proceedings*. IEEE, 1–6.

Jerry Chih-Yuan Sun. 2014. Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Comput. Educ.* 72 (Mar. 2014), 80–89.

S. Shyam Sundar, Jeeyun Oh, Saraswathi Bellur, Haiyan Jia, and Hyang-Sook Kim. 2012. Interactivity as self-expression: A field experiment with customization and blogging. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems (CHI'12)*. ACM Press, 395.

Ben Swift, Henry Gardner, and Alistair Riddell. 2010. Engagement networks in social music-making. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction (OZCHI'10)*. ACM Press, 104.

Daniel Szafir and Bilge Mutlu. 2012. Pay attention!: Designing adaptive agents that monitor and improve user engagement. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems (CHI'12)*. ACM Press, 11.

Jay Shiro Tashiro and David Dunlap. 2007. The impact of realism on learning engagement in educational games. In *Proceedings of the 2007 Conference on Future Play (Future Play'07)*. ACM Press, 113.

Nick Taylor, Justin Marshall, Alicia Blum-Ross, John Mills, Jon Rogers, Paul Egglestone, David M. Frohlich, Peter Wright, and Patrick Olivier. 2012. Viewpoint: Empowering communities with situated voting devices. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems (CHI'12)*. ACM Press, 1361.

Choo-Yee Ting, Wei-Nam Cheah, and Chiung Ching Ho. 2013. Student engagement modeling using bayesian networks. In *Proceedings of the 2013 IEEE International Conference on Systems, Man, and Cybernetics*. IEEE, 2939–2944.

Holly Tootell, Melinda Plumb, Colin Hadfield, and Linda Dawson. 2013. Gestural interface technology in early childhood education: A framework for fully engaged communication. In *Proceedings of the 2013 46th Hawaii International Conference on System Sciences*. IEEE, 13–20.

Phil Turner. 2010. The anatomy of engagement. In *Proceedings of the 28th Annual European Conference on Cognitive Ergonomics (ECCE'10)*. ACM Press, 59.

Jaime Urquiza-Fuentes and J. Ángel Velázquez-Iturbide. 2012. Comparing the effectiveness of different educational uses of program animations. In *Proceedings of the 17th ACM Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE'12)*. ACM Press, 174.

Erik D. Van Der Spek. 2012. Towards designing for competence and engagement in serious games. In *Proceedings of the 3rd International Conference on Serious Games Development and Applications (SGDA'12)*, Vol. 7528. Springer Berlin Heidelberg, 98–109.

H. C. van Vugt, E. A. Konijn, J. F. Hoorn, I. Keur, and A. Eliëns. 2007. Realism is not all! User engagement with task-related interface characters. *Interact. Comput.* 19, 2 (Mar. 2007), 267–280.

Henriette C. van Vugt, Johan F. Hoorn, Elly A. Konijn, and Athina de Bie Dimitriadou. 2006. Affective affordances: Improving interface character engagement through interaction. *Int. J. Hum.-Comput. Stud.* 64, 9 (Sept. 2006), 874–888.

Marynel Vázquez, Aaron Steinfeld, Scott E. Hudson, and Jodi Forlizzi. 2014. Spatial and other social engagement cues in a child-robot interaction: Effects of a sidekick. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction (HRI'14)*. ACM Press, 391–398.

Jane Webster and Jaspreet S. Ahuja. 2006. Enhancing the design of web navigation systems: The influence of user disorientation on engagement and performance. *MIS Quart.* 30, 3 (Sept. 2006), 661–678.

Jane Webster and Hayes Ho. 1997. Audience engagement in multimedia presentations. *ACM SIGMIS Database* 28, 2 (Apr. 1997), 63–77.

Jennifer Whitson, Chris Eaket, Brian Greenspan, Minh Quang Tran, and Natalie King. 2008. Neo-immersion: Awareness and engagement in gameplay. In *Proceedings of the 2008 Conference on Future Play Research, Play, Share (Future Play '08)*. ACM Press, 220.

Jon Whittle, William Simm, Maria-Angela Ferrario, Katerina Frankova, Laurence Garton, Andrée Woodcock, Baseerit Nasa, Jane Binner, and Aom Ariyatum. 2010. VoiceYourView: Collecting real-time feedback on the design of public spaces. In *Proceedings of the 12th ACM International Conference on Ubiquitous Computing (Ubicomp'10)*. ACM Press, 41.

Eric N. Wiebe, Allison Lamb, Megan Hardy, and David Sharek. 2014. Measuring engagement in video game-based environments: Investigation of the user engagement scale. *Comput. Hum. Behav.* 32 (Mar. 2014), 123–132.

Noortje Wiezer, Maartje Bakhuys Roozeboom, and Esther Oprins. 2013. Serious gaming used as management intervention to prevent work-related stress and raise work-engagement among workers. In *Proceedings of the 4th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management: Human Body Modeling and Ergonomics (DHM'13)*, Vol. 8026. Springer Berlin Heidelberg, 149–158.

Alyssa Wise, Juyu Chang, Thomas Duffy, and Rodrigo del Valle. 2004. The effects of teacher social presence on student satisfaction, engagement, and learning. *J. Educ. Comput. Res.* 31, 3 (Jun. 2004), 247–271.

Lesley Xie, Alissa N. Antle, and Nima Motamedi. 2008. Are tangibles more fun?: Comparing children's enjoyment and engagement using physical, graphical and tangible user interfaces. In *Proceedings of the 2nd International Conference on Tangible and Embedded Interaction (TEI'08)*. ACM Press, 191.

Qianli Xu, Liyuan Li, and Gang Wang. 2013. Designing engagement-aware agents for multiparty conversations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'13)*. ACM Press, 2233.

Elad Yom-Tov, Mounia Lalmas, Georges Dupret, Ricardo Baeza-Yates, Pinard Donmez, and Janette Lehmann. 2012. The effect of links on networked user engagement. In *Proceedings of the 21st International Conference companion on World Wide Web (WWW'12 Companion)*. ACM Press, 641.

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