On the Application of Motivation Theory to Human Factors/Ergonomics: Motivational Design Principles for Human–Technology Interaction

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Objective: Motivation is a driving force in human–technology interaction. This paper represents an effort to (a) describe a theoretical model of motivation in human technology interaction, (b) provide design principles and guidelines based on this theory, and (c) describe a sequence of steps for the evaluation of motivational factors in human–technology interaction.

Background: Motivation theory has been relatively neglected in human factors/ergonomics (HF/E). In both research and practice, the (implicit) assumption has been that the operator is already motivated or that motivation is an organizational concern and beyond the purview of HF/E. However, technology can induce task-related boredom (e.g., automation) that can be stressful and also increase system vulnerability to performance failures.

Method: A theoretical model of motivation in human–technology interaction is proposed, based on extension of the self-determination theory of motivation to HF/E. This model provides the basis for both future research and for development of practical recommendations for design.

Results: General principles and guidelines for motivational design are described as well as a sequence of steps for the design process.

Conclusion: Human motivation is an important concern for HF/E research and practice. Procedures in the design of both simple and complex technologies can, and should, include the evaluation of motivational characteristics of the task, interface, or system. In addition, researchers should investigate these factors in specific human–technology domains.

Application: The theory, principles, and guidelines described here can be incorporated into existing techniques for task analysis and for interface and system design.

Keywords: motivation and technology, motivation and human factors/ergonomics, hedonomics, eudaimonic design, self-determination theory, work motivation

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INTRODUCTION

Human factors and ergonomics (HF/E) theories and research have mostly emphasized sensory/perceptual, cognitive, and psychomotor processes (Proctor & Van Zandt, 2008; Sanders & McCormick, 1993; Wickens, Lee, Liu, & Gordon-Becker, 2003), although there has been some work on how emotion and personality affect human–technology interaction (e.g., Hancock, Pepe, & Murphy, 2005; Helander & Tham, 2003; Szalma, 2008, 2009). With respect to emotion, authors of much of this work have been concerned either with the influence of stress on performance (e.g., Broadbent, 1971) and human–machine interaction (Hancock & Szalma, 2008) or with the design of interfaces and tasks to be emotionally satisfying or even pleasurable (e.g., Hancock et al., 2005; Helander & Tham, 2003; Jordan, 2000; McDonagh, Hekkert, Van Erp, & Gyi, 2004; Norman, 2004).

Motivation Psychology and HF/E

Motivation theory has been mostly neglected in HF/E theory and research (for a brief discussion, see Szalma, 2009). The (implicit) assumption has been that the operator or user is already motivated or that lack of motivation can be ameliorated by application of organizational science—that motivation is outside the purview of HF/E. However, it is now clear that technology itself can induce or exacerbate boredom (Cooke, Cummings, Hancock, Marras, & Warm, 2010; Cummings, Mastracchio, Thornburg, & Mkrtchyan, 2013; Hancock, 2013) and stress (e.g., Szalma, Hancock, & Hancock, 2012), which can place performance at risk (Hancock & Szalma, 2008). In fact, boredom and disengagement can be considered adaptive responses of individuals to poorly designed environments (Hancock, 2013), and the prevalence of boredom in technology use underscores the need for consideration of motivation theory in HF/E. As recently noted by Hancock (2013), lack of motivation in many contexts results from failures not of the person but in the design of the task itself. Fortunately, insights from motivation psychology developed over the previous half century can potentially address these issues in the design of technology.

Although motivation has been recognized to be an important factor in technology design (e.g., Leventhal & Barnes, 2008; Nielson, 1993; Olphert & Damodaran, 2004; Shackel, 1986), the theoretical constructs related to motivation have been phrased in poorly defined and nontheoretical terms. There have been exceptions, such as research on flow experience associated with technology (e.g., Montgomery, Sharafi, & Hedman, 2004; Pace, 2004; Pilke, 2004), technology acceptance (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989, 1992; Venkatesh, 2000), and most generally, work motivation (Kanfer, Chen, & Pritchard, 2008). In addition, there has been substantial research on the influence of incentives and arousal on performance as well as work on the cognitive processes associated with motivation (e.g., expectancy, goal value; for a review, see Matthews, Davies, Westerman, & Stammers, 2000). However, most of these exceptions either are domain specific (e.g., human–computer interaction; video games) or are focused on the broader context in which a task is performed (e.g., work settings; the relationships among motivation, stress, and performance) rather than on the motivational effects of the technology itself.

To date, there are no broadly applicable design principles for human–technology interaction based on psychological theories of motivation, and most practical recommendations for enhancing motivation that do exist are not well grounded in psychological theory, which can limit the effectiveness of their applicability. For instance, Thompson (2004) discussed motivation "theory" but cited no scholarly work (except for Maslow, 1943) to identify theories or to apply them, remarking only that there is no "single overriding theory which applies to all situations" (p. 333). Although it is true that multiple theories exist, it is not the case that there are no general theories of motivation applicable to human–technology interaction. There are a few theories that are sufficiently broad in scope to be useful for developing general HF/E principles for motivational design.

It is proposed here that a set of general principles for motivational design be developed for broad application in a manner analogous to that for principles of display and control design, that is, by deriving principles from psychological theory. One can imagine that many of the principles of display design would have been less powerful if they had not been derived from and based on theories of sensation, perception, and cognition. Although it is likely that many practitioners already consider user motivation in their design work, to date, these considerations have not been formalized in HF/E theory and research. Hence, the present work is an effort to (a) describe a theoretical model of motivation in human technology interaction based on self-determination theory (SD-theory; Deci & Ryan, 1985; Ryan & Deci, 2000), (b) provide general design principles and guidelines based on this theory, and (c) describe a sequence of steps for the evaluation of motivational factors in human–technology interaction. These steps for application parallel those that have been previously described for personality and individual differences (Szalma, 2009).

Why Motivation?

Motivation has been conceptualized as a continuous stream of behavior comprising three components: (a) direction (goals), (b) energy (allocated to the pursuit of those goals), and (c) persistence (versus a change) in goal pursuit (Atkinson & Birch, 1978; Petri & Govern, 2013). It is also well established that the structure of environments influences motivational states (Petri & Govern, 2013; Reeve, 2005). For instance, factors related to feedback or rewards, to autonomy, and to self-efficacy have been implicated in motivational responses to environmental conditions (e.g., Bandura, 1997; Deci & Ryan, 1985). To the extent that these factors are generally important in determining human behavior, they must also influence how humans respond to technology. That is, technology, as a component of the environment, affects goals, efficacy beliefs, and the energization of behavior. However, technology is an aspect of the environment that humans themselves create.

The utility for including motivation theory into HF/E design is apparent from consideration of multiple research literatures, including motivation theory itself (Deci & Ryan, 1985; Ryan & Deci, 2000), technology acceptance (Venkatesh, 2000), pleasurable or hedonomic design (Hancock et al., 2005; Jordan, 1998, 2000; McLaughlin, Gandy, Allaire, & Whitlock, 2012), boredom and monotony (Davies, Shackleton, & Parasuraman, 1983; Fisher, 1993; Scerbo, 1998; Smith, 1981), and work motivation (Kanfer et al., 2008; Luczak, Kabel, & Licht, 2012). Research from these diverse areas, considered from the HF/E perspective, converges on the clear conclusion that consideration of the motivational effects of technology (or of any aspects of the environment) is crucial to the attainment of successful outcomes (e.g., usability, performance, mitigation of workload and stress).

The rationale for incorporating motivation theory into HF/E research and practice derives from concerns that are familiar to the HF/E community. These issues are (a) the degree to which an interface supports the person in attaining his or her immediate (and in some cases, long-term) goals and (b) the meaning of the immediate activity and the general contextualized activity for the user. This second issue addresses the *kinds* of goals pursued as well as *why* a person pursues them. From this perspective, the central question for design is how to structure technology to support motivated behavior that facilitates both performance and the well-being of the users (i.e., to enable effective performance without inducing stress and to facilitate, when possible, the experience of a pleasant interaction or activity).

Consideration of motivation theory addresses the issue of how goals (and the contexts in which they are pursued) should be structured, which in turn will drive how the technology is designed to support their attainment. Note that considerations of system and user goals are not new to HF/E. The centrality of motivation is reflected in one of the first and most central questions in technology design: “What is the goal for the system?” However, the motivational state of the user has not been formally or systematically integrated into HF/E theory, research, or practice.

In essence, motivation is important for human–technology interaction because such circumstances are a subset of human experience and because motivational processes energize and direct human activity. Motivation is a central driving force in the design and creation of tools: Humans do not create artifacts without a purpose, and humans use tools for activities that are meaningful to them (Hancock, 2009). Hence, motivation theory should inform the design of these tools in order to maximize the benefits to the users.

It is useful to consider the consequences of *not* incorporating motivation theory into design principles. One cannot prove a negative; that is, one cannot establish that a system failure that has occurred would not have occurred if operator motivation had been considered. However, variables investigated in motivation research (e.g., interest; Sansone & Smith, 2000; Sansone, Thoman, & Smith, 2010; boredom and its mitigation, Fisher, 1993) are also relevant to HF/E domains, for example, prolonged driving, automation, and autonomous systems. It is not the case that if the motivational state of the user is ignored during the design process, the technology or system will fail with certainty or even with a high probability. Humans and the systems they use are often resilient; the former are adaptive to suboptimal circumstances, and the latter are often designed to be error tolerant. Indeed, Olphert and Damodaran (2004) noted that the relative lack of attention to “nonfunctional” (i.e., affective) requirements by designers and users alike may be attributed to the fact that people are not accustomed to systems in the workplace that are rewarding and fulfilling to use. However, even tolerant and resilient systems have limits in stability, and the strain of stress, workload, and fatigue can place humans and the systems they operate into states of adaptive instability and increased risk of failure (Hancock & Warm, 1989; Hockey, 1997). Hence, to ignore operator motivation is to neglect an important but vulnerable aspect of human–technology interaction, which may increase the risk of performance impairment that may result in adverse effects on the well-being of the users.

As a practical illustration, consider tasks in which there are well-documented effects of boredom, fatigue, and stress. The importance of motivation is well established for performance in work environments in general (Kanfer et al., 2008; Luczak et al., 2012), but worker motivation is particularly fragile for monotonous tasks or jobs (Davies et al., 1983; Fisher, 1993). These include automation, long-distance driving, monitoring, and monotonous, repetitive tasks. For automation in particular, the motivational issue associated with supervisory control (i.e., the problem of boredom) has been recently identified as a crucial concern (Cooke et al., 2010; Cummings et al., 2013). In all these contexts, the operators are generally motivated to engage in the task, and they realize that their safety depends on successful task performance. Yet they are bored, tired, and stressed and are thus vulnerable to performance failure. Furthermore, these effects are likely iatrogenic, that is, induced by the design of the technology itself (Hancock, 2013).

These circumstances can be potentially mitigated by consideration of the relation of the operator to the goal, that is, the *motivational* relationship of the person to the task goal. Boredom, fatigue, and stress can be reduced by designing task goals to be well aligned to important personal goals of the individual and by providing the person with opportunities for effective, autonomous performance of the task. Consideration of operator motivation will facilitate attainment of the design goals of "satisfaction" (International Organization for Standardization [ISO], 1998), "pleasing experience" (Nielson, 1993), and "task match" (Eason, 1984) associated with models of usability.

Prior Applications of Motivation and Emotion to Human–Technology Interaction

Emotion and usability. Although motivation has not been adequately addressed in usability research, the importance of consideration of emotion in design is well known (e.g., Jordan, 1998, 2000; McDonagh et al., 2004; Norman, 2004). For instance, Jordan (2000) noted that pleasure in using a product requires more than (functional) usability but also the effects the product has on emotional response. Functionality is crucial for product effectiveness and a necessary condition for pleasurable interaction (Hancock et al., 2005), but nonfunctional requirements, such as affective experience, may be just as important (Olphert & Damodaran, 2004). This concept is relevant to motivation because emotions are, in part, a response to goal status (Lazarus, 1991). That is, emotional responses to technology or to performing a task are a result of cognitive appraisals regarding current system state relative to a goal state.

As noted previously, individuals use technology for goal-directed activity (Hancock, 2009). Well-designed technology supports attainment of these goals and does so in a manner that requires the least amount of energy. In essence, this is the meaning of the term *usability*, which may be defined in terms of achieving "specified goals" in an "efficient and satisfying manner" (ISO, 1998; Leventhal & Barnes, 2008). Furthermore, psychological processes related to nonfunctional requirements are included in formal treatments of usability. For instance, models of usability identify user attitudes (Shackel, 1986), whether a user experiences an interface as subjectively pleasing (Nielsen, 1993), or whether the user is motivated to use the technology (Eason, 1984). Note that with respect to the latter model, motivation was conceptualized as a goal-directed construct, but the model did not address the factors that drive intrinsic versus extrinsic motivation or the importance of personal autonomy in goal selection and pursuit.

In general, usability models have not included a description of the motivational structures or processes underlying user intentions and behavior. Authors of texts on usability (e.g., Leventhal & Barnes, 2008) mention the importance of motivation, but they do not analyze it further than to note that motivated users will have more successful and/or pleasant interactions with the interface. This approach neglects analysis of the relation of the person to the goal, for example, the importance of both adopting and attaining the goal for the person and his or her well-being. Following traditional information-processing perspectives, HF/E seems to treat all goals as occurring on a single continuum of motivational intensity and to assume that goals differ only in quantity and not in kind. However, there is substantial evidence that the kind of goal pursued affects the form of motivation as well as its intensity (Deci & Ryan, 1985; Ryan & Deci, 2000).

Motivation and technology acceptance. One of the most well-known applications of motivation research to technology use is the technology acceptance model (TAM). TAM was developed from research on user acceptance of computer technology (Davis, 1989; Davis et al., 1989, 1992). According to this model, technology use is directly determined by behavioral intention to use it, and this intention is determined by attitudes of the user toward the technology. Specifically, intention is determined by the *perceived usefulness* of the technology (i.e., the utility or instrumentality of the technology for goal attainment) and *perceived ease of use* (i.e., the usability of the technology). Research has established that perceived usefulness is influenced by perceived ease of use and that the latter is determined by multiple factors that include self-efficacy, perception of control, computer anxiety, computer playfulness, enjoyment, and "objective usability" (i.e., the actual level of effort required to use the technology to complete a specific task; Venkatesh, 2000).

The evidence generally supports the validity of TAM (for meta-analytic reviews, see King & He, 2006; Schepers & Wetzels, 2007), including its application to automation (Ghazizadeh, Lee, & Boyle, 2012), but the model does not explain how the *relational meaning* of the interaction affects user performance or well-being. TAM has been linked to a distinction between extrinsic and intrinsic motivation (Davis et al., 1992; Venkatesh, 2000), but the model does not account for different forms of extrinsic motivation that occur as a function of different levels of psychological need satisfaction (Ryan & Deci, 2000), nor does it account for the importance of the degree of internalization of goals (Sheldon & Kasser, 1995). These structures and processes determine the form and the magnitude of motivation. In addition, TAM specifies facilitating conditions for higher perceived ease of use (i.e., providing support for self-efficacy and control, reducing anxiety, and increasing the playfulness of the system; Venkatesh, 2000), but it does not address the process by which this facilitation occurs.

In essence, TAM does not completely describe the motivational structures and processes that determine the "why" of technology acceptance. Work on TAM does establish, however, that attention to factors that influence user motivation can have positive outcomes, that is, user acceptance of technology (e.g., the design of a medication management device; Chiou et al., 2014). Further, the model provides validated instruments for the measurement of perceived ease of use and perceived usefulness (Davies et al., 1992; Venkatesh, 2000), which may facilitate applications of motivational design principles.

In a subsequent section of this paper, it is argued that each of the facilitating conditions identified in TAM can be supported by creating structures that strengthen the experience of satisfaction of basic psychological needs. From this perspective, the factors identified in TAM are elements of a larger set of conditions that support psychological need satisfaction and thereby facilitate intrinsic and internalized extrinsic motivation.

CHOICE OF THEORY: SHIFTING THE EMPHASIS FROM GOALS TO MEANING

There are many theoretical perspectives that have contributed to our collective understanding of motivation by identifying cognitive processes that influence behavior, including expectancy and value (Vroom, 1964), self-efficacy (Bandura, 1997), and goal setting (Latham & Locke, 2007; Locke & Latham, 1990, 2002, 2006). Theories that emphasize goal setting (Locke & Latham, 1990) or cybernetic control of behavior (Carver & Scheier, 1998) are relevant because these concepts are also used widely in HF/E. Although these particular theories may therefore be useful for describing the microstructure of dynamic fluctuations in motivational state in real time, they are not sufficient to address the issues of purpose that drive human–technology interaction, that is, the *meaning* of the interaction for the human user (cf. Hancock, 2009, 2013).

For instance, goal-setting theory has been applied across multiple contexts (Latham & Locke, 2007; Locke & Latham, 1990, 2002, 2006), and it has potential for application to evaluation of the effect of task goals on human–technology interaction. Goals are obviously an important component of efforts to design technology to support user activities, but there are other aspects of motivation relevant to HF/E issues that goal-setting theory does not address (i.e., the "why" of goal selection; Sheldon, Ryan, Deci, & Kasser, 2004). Similarly, cybernetic approaches also describe *how* goals are achieved, but they are less effective in identifying the factors that determine the "what" and "why" of goal selection and pursuit (Deci & Ryan, 2000). SD-theory (Deci & Ryan, 1985; Ryan & Deci, 2000) addresses these latter issues.

SD-Theory

SD-theory is a broad perspective that distinguishes intrinsic motivation as qualitatively different from forms of extrinsic motivation (Deci & Ryan, 1985, 2000; Ryan & Deci, 2000, 2008). Note that researchers in this area refer to SD-theory as "SDT." Here it is referred to as SD-theory to avoid confusion with the signal detection theory familiar to the HF/E and applied experimental psychology community. As I have previously noted (Szalma, 2009), the use of the abbreviation SDT for two very different theories underscores the historical separation between motivation psychology and HF/E.

Intrinsic motivation is defined as motivation in which the source is the "inherent satisfaction" the individual derives from the behavior (Ryan & Deci, 2008). The purpose or goal for the behavior is in the experience of the activity itself. In contrast, *extrinsic motivation* occurs when the motivational source of behavior is an external agent, that is, when the motivation for an activity is to attain a goal separate from the activity itself (e.g., a means to an end). The distinction between intrinsic and extrinsic motivation has been well established empirically, and several factors have been identified that influence whether behavior is intrinsically or extrinsically motivated (for a meta-analytic review, see Deci, Koestner, & Ryan, 1999). The distinction between intrinsic and extrinsic motivation differentiates SD-theory from other dominant models that propose a central self-regulatory (Carver & Scheier, 1998) or goal-setting mechanism (Locke & Latham, 1990) as the primary drivers of a unitary motivation system.

Psychological needs. In SD-theory, three innate psychological needs are considered the basis for human motivation and the self-regulation of behavior. These are the needs for *autonomy* (experience of choice, personal agency, volition, self-determination; cf. Dember & Earl, 1957), *competence* (effective interactions with the environment; effectance motivation; White, 1959), and *relatedness* (a supportive social connectedness with others, encompassing both healthy attachment and intimacy; Ryan & Deci, 2001). Note that psychological needs can serve both as outcomes to be satisfied (i.e., experiential requirements) and as motives that energize and direct behavior (Sheldon, 2011; Sheldon & Gunz, 2009; Sheldon & Schuler, 2011). In the present context, need satisfaction can thus serve both as an outcome of technology use and as a motivation for using it (e.g., Sheldon, Abad, & Hintsch, 2011).

Goals and the self. It is well established that not all goals are equivalent in their value to a given individual, and there is substantial evidence that the relation of the goal to the self of the person affects the experience of the activity. For instance, when goals are well matched to values that have been integrated into the person's self (i.e., when goals are *self-concordant*; Sheldon & Kasser, 1995), individuals are more engaged in the activity, they experience more positive affect, and they exhibit greater resilience when confronted with challenge (Ryan & Deci, 2008; Sheldon & Kasser, 1995). Goals that are externally imposed on the person, with limited or no opportunity for self-determined (autonomous) behavior, lead to greater vulnerability to stress and fatigue and to a less satisfying experience. This result has been observed in a variety of contexts, including work, sport, and education, and, more recently, has been extended to technological environments as well (e.g., Przybylski, Deci, Rigby, & Ryan, 2014; Ryan, Rigby, & Przybylski, 2006; Sheldon et al., 2011).

Forms of extrinsic motivation: The importance of autonomy. In the overwhelming majority of tasks involving human use of technology (or human behavior in general), there is a limited number of opportunities for intrinsically interesting activity. Thus, intrinsic motivation may not be a realistic goal for many applications, a practical limitation that has been recognized by self-determination theorists themselves (e.g., Gagné & Deci, 2005). However, there are four forms of extrinsic motivation that vary in the

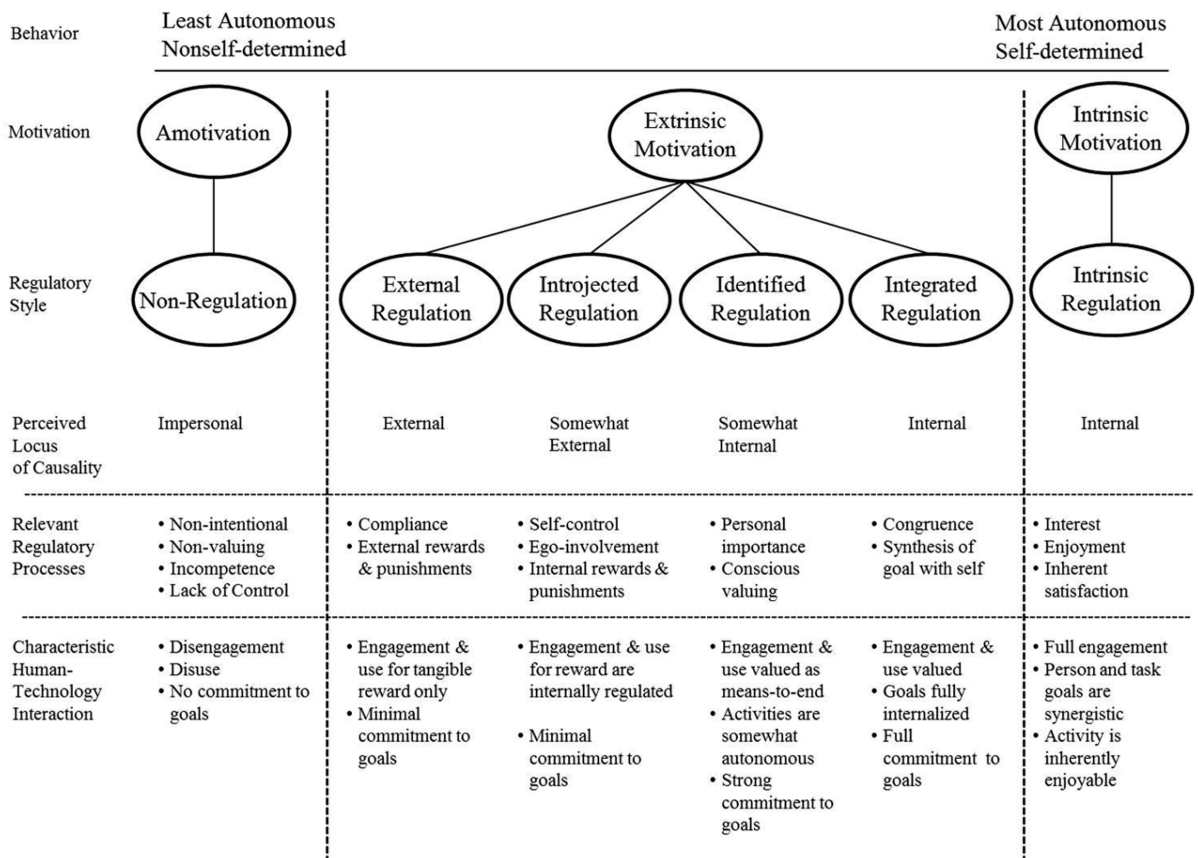

Figure 1. Different forms of motivation and their associated levels of autonomy, regulatory style, and perceived locus of causality. The processes relevant to each regulatory style and the potential effect of each type of motivation on human–technology interaction are also shown. Adapted from Ryan and Deci (2000).

degree to which the regulation of behavior is autonomous and the goal is integrated with the person's values (see Figure 1). Which form of extrinsic motivation occurs is determined by the degree of internalization of the value of the activity. *Internalization* refers to a process by which a person accepts and adopts the value of a goal and integrates it with their identity and sense of self (Deci & Ryan, 2000; Ryan & Deci, 2000). Internalization of a goal is associated with the experience of greater autonomy and competence in the goal-related activity (Deci & Ryan, 1985; Ryan & Deci, 2000; Stone, Deci, & Ryan, 2009).

The lowest level of autonomy is *external regulation*, in which there is no internalization of the goal and behavior is directly regulated by the response contingencies of an external agent (e.g., tangible rewards or punishments). The second level is *introjected regulation*, composed of reward/punishment contingencies that the individual himself or herself regulates (these may include ego-related goals for self-esteem, such as pride or avoidance of shame). In this case, the internalization of the goal is minimal and limited to the self-control of the contingency regulation.

Identified regulation is characterized by behavior that is not linked to specific rewards or punishments, but the person values the activity as a means to attaining a separate but personally important goal. However, the activity remains a requirement imposed by external forces. The most autonomous form of extrinsic motivation is *integrated regulation*, in which the value of the goal has been fully integrated with the person's values (the "self"; Deci & Ryan, 2000; Ryan & Deci, 2000; Sheldon & Elliot, 1999). It is similar to intrinsic motivation in the degree of autonomy in self-regulation, but it differs from the latter in that it is behavior that results from the utility of the goal for other personal (but highly valued and integrated) goals rather than inherent interest in the activity itself.

Facilitating Intrinsic Motivation and Autonomous Extrinsic Motivation

Intrinsic motivation is facilitated by environments that support and provide opportunities for autonomous behavior and that promote experiences of competence and relatedness. Conditions that interfere with or thwart satisfaction of these needs undermine intrinsic motivation and induce extrinsic motivation (or no motivation—"amotivation"; Ryan & Deci, 2000) for the activity. Thus, technology that supports need satisfaction will facilitate intrinsic motivation and autonomous extrinsic motivation (identified or integrated regulation) for using the technology. Although intrinsic motivation may not be a realistic goal for practical application (but see Csikszentmihalyi, 1990; Hancock et al., 2005), identified and integrated regulation are realistic and possible. Attaining such self-regulation requires provision of *real* autonomy to operators (*perceived* autonomy is necessary but not sufficient). Facilitating competence (i.e., effective engagement with the environment; Deci & Ryan, 1985) is also crucial, and to some extent this is addressed by design principles that support usability.

Application of SD-Theory to Human–Technology Interaction

There have been few applications of SD-theory to issues pertaining to human–technology interaction, but extant examples indicate that technology affects user motivation as a function of the degree to which it supports need satisfaction. The beneficial effects of facilitating autonomy and competence have been observed in the context of acceptance of new information technology (Mitchell, Gagné, Beaudry, & Dyer, 2012), computer-based self-management of diabetes (Williams, Lynch, & Glasgow, 2007; Williams, McGregor, Zeldman, Freedman, & Deci, 2004), and video game play (Przbylinski, Rigby, & Ryan, 2010; Ryan et al., 2006).

In the case of video game use, one of the variables that affect the experience of autonomy and competence is the "intuitiveness" of the controls. Ryan et al. (2006) reported that the ease of use of an interface, in this case, a game control device, directly and positively affected need satisfaction, which increased intrinsic or integrated extrinsic motivation for the activity. Both autonomy and competence also predicted enjoyment, preference for playing the game, and free choice of play (a behavioral measure of intrinsic motivation; Deci & Ryan, 1985). In addition, competence (but not autonomy) was positively related to the experience of presence in the game. It should be noted that Ryan et al. used a relatively older game (*Mario 64*), so these effects would likely be stronger in games with more complex features as well as in virtual reality contexts (e.g., Partala, 2011; Verhagen, Feldberg, van den Hooff, Meents, & Merikivi, 2012). There is initial evidence to support this contention (Przbylski et al., 2014).

Technology may also play a role in satisfying the need for relatedness. For instance, Sheldon et al. (2011) examined the relationship of Facebook use to perceptions of connectedness and disconnectedness with others (the latter indicating that satisfaction of the need for relatedness is blocked). They reported that higher levels of disconnectedness were associated with increased use of Facebook and that connectedness perceptions were an outcome of that use. Thus, psychological need dissatisfaction can motivate behavior, and need satisfaction may then be an outcome of that activity depending on the motivational structure of the environment (Sheldon, 2011).

There is evidence that autonomous motivation can be facilitated even for monotonous tasks. Deci, Eghrari, Patrick, and Leone (1994) asked participants to perform a monotonous vigilance task in which they monitored a video display for the occasional appearance of a small dot of light at randomly determined locations. They evaluated the effects of instruction manipulation on the degree and type of internalization task goals, as measured by time spent engaged in the task during a free activity period as well as by ratings of perceived choice, perceived usefulness, and interest/enjoyment of the task. They reported that autonomous motivation was enhanced by providing participants with a meaningful rationale for the activity, by acknowledgement that the task was uninteresting, or by

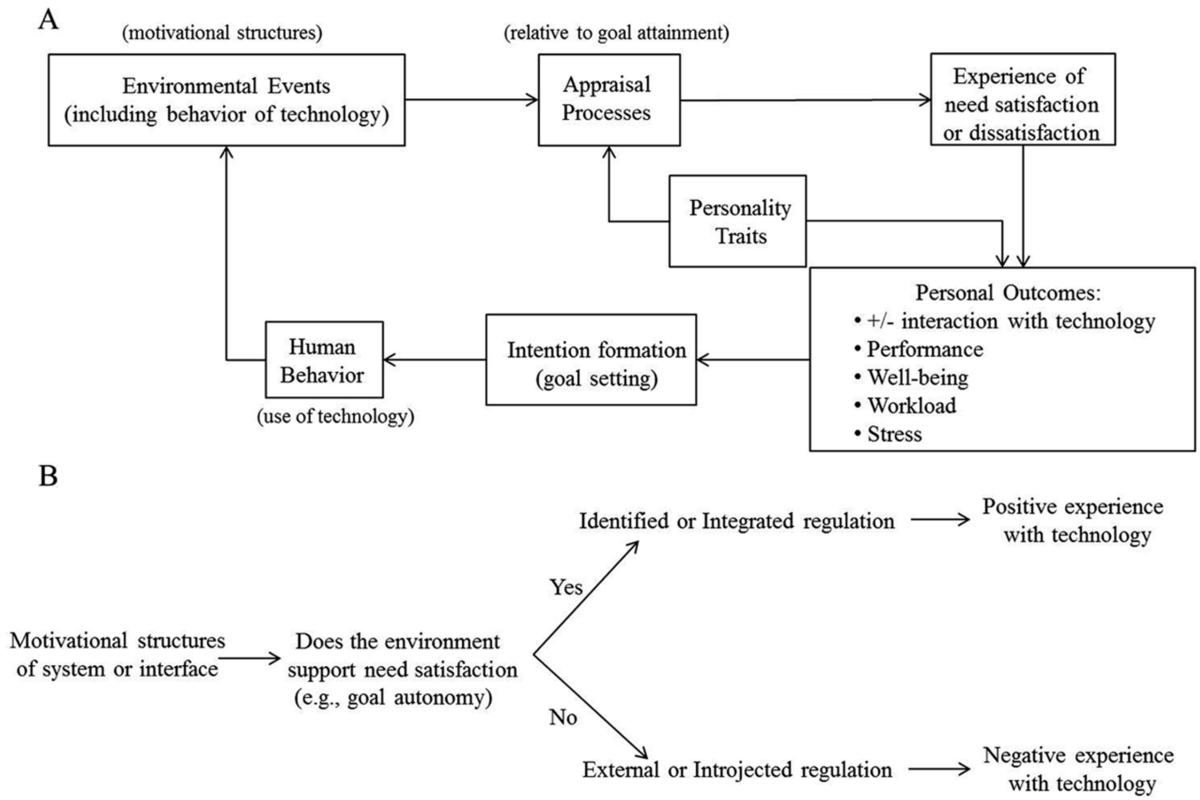

Figure 2. (A) A theory of motivation and human–technology interaction. (B) An illustration of how the characteristics of a task or interface affect need satisfaction and the resulting consequences for behavioral self-regulation and human–technology interaction.

using instructions that were worded to minimize the experience of externally controlled task engagement (e.g., by emphasizing choice and autonomous behavior versus using words such as *should* or *must*). Hence, the way in which participants were oriented toward the task affected their experience of autonomous motivation. Note that because the purpose for their study was to test the effects of instructions on goal internalization, Deci et al. (1994) did not report performance data.

A THEORY OF MOTIVATION AND HUMAN–TECHNOLOGY INTERACTION

The general model and the regulatory outcomes of psychological need support are shown in Figures 2A and 2B, respectively. Note that personality traits are included in Figure 2A because of their known effects on appraisal (Lazarus, 1991; Lazarus & Folkman, 1984) and on personal outcomes related to task performance and cognitive state (Szalma, 2008, 2009, 2012).

Motivational Structures and Cognitive Evaluation

A *motivational structure* is a set of structures in the environment that offers opportunities for the experience of autonomy, competence, and relatedness (i.e., for basic psychological needs to be met). This concept is similar to the term *motivational affordance* as used by Szalma (2009) and Zhang (2008). An *environmental structure* facilitates autonomy if it enables personal agency and self-regulation of activities (freedom of choice, self-determination); an environmental structure facilitates competence if it enables effective use of technology or, in some circumstances, learning and skill development; an environmental structure facilitates relatedness if it enables mutually supportive social relationships and a positive, nurturing relationship between the person and the organization, social group, or the technology itself.

Individuals use technology in order to achieve both short- and long-term goals ("intention formation" in Figure 2A). The motivational structures in the environment constrain human use of the technology. Response to the technology, in terms of performance, satisfaction, acceptance, likelihood of future use, and affective response, will be influenced by cognitive appraisals of goal support (i.e., cognitive evaluations; Deci & Ryan, 1985) and the subsequent experience of need satisfaction and the resulting outcomes (see "personal outcomes" in Figure 2A).

The Role of Psychological Needs in Human–Technology Interaction

Essentially, human response to technology depends not only on goal outcomes (individuals adapt relatively well to poor design via compensatory mechanisms; Hancock & Warm, 1989; Hockey, 1997, 2003) but also on the experience of the interaction itself (i.e., the "experience of need satisfaction"; see Figure 2B). For instance, using an ATM or a word-processing program may result in the same task outcome for two people (completing a financial transaction; writing a document), but if one person uses a clumsy, poorly designed interface, the experience of the interaction (and the motivation for future use of the technology) will likely be external or introjected regulation. If the interaction is pleasant for the second individual because the technology supported autonomous engagement in the activity, his or her experience would likely be associated with identified, integrated, or intrinsic regulation (depending on the degree to which task goals are internalized or the activity itself is interesting). The crucial difference in the motivational experience of these individuals results not from the task goal per se but from how the appraised progress toward goal attainment supports the experience of satisfaction of the three basic psychological needs.

The experience of pleasure or displeasure elicited by the attributes of the object or task (Jordan, 2000) are symptoms of the facilitation (pleasure) or thwarting (displeasure) of psychological need satisfaction. If the technology or task structure facilitates experience of autonomy and competence, the interaction will be positive and the motivation for using it will be more autonomous and less controlled. If the task or interface structure is designed poorly, competency (not only skill but, more generally, effective interaction) and autonomy can be undermined. Of course, there can also be too little structure—that is, providing multiple options can induce indecision or poor choices (Schwarz, 2004) because the information-processing requirements exceed capacity (Dember & Earl, 1957). Conversely, overly rigid task structures can reduce autonomous motivation and, in some circumstances (e.g., automation), increase the risk of loss of competence and relatedness.

EUDAIMONIC DESIGN: PRINCIPLES AND PROCEDURES

Eudaimonic approaches to motivation involve viewing well-being as a high level of psychological functioning and self-realization of nonmaterial goals (in particular, goals that, when attained, satisfy the three basic needs) rather than attaining the purely hedonic goals of pleasure or pain avoidance (see Ryan & Deci, 2001, for a more detailed treatment of this issue). Designing technology to enhance well-being in terms of effective psychological functioning may thus be termed *eudaimonic design* as a contrast to *hedonomic design* (for a description of the latter, see Hancock et al., 2005; Helander & Tham, 2003). That is, in addition to satisfying goals for short-term pleasure (hedonomics), principles for motivational design can also facilitate long-term well-being that is characterized by effective psychological functioning, or eudaimonia (Ryan & Deci, 2001). It is my contention that designing only for pleasure or purely hedonic goals is not necessarily designing for well-being or eudaimonic goals. For instance, engaging in video game play several hours per day may provide opportunities for short-term pleasure but it also may induce poor long-term psychological or physical health (e.g., Park, 2007; Smyth, 2007).

Principles for Motivational Design

The principles listed in Table 1 describe the general issues to be addressed in designing a task or an interface to support the experience of autonomy, competence, and relatedness. Figure 3 illustrates how the previously described motivation concepts can be incorporated into the general design process of HF/E. Note that when possible, these principles should be applied at

TABLE 1: Principles of Eudaimonic Design

1. **Functional design:** In trade-offs among design principles, meeting functional criteria is a necessary but not sufficient condition for motivational usability (i.e., an interface will have low motivational usability if it has poor function; cf. Hancock, Pepe, & Murphy, 2005). This includes ensuring that task demands closely match the skill level of the user and that there is a high level of perceived ease of use (Venkatesh, 2000).
2. **Eudaimonic design:** Interfaces that are high in motivational usability will be those that, through their use, satisfy the individual's needs for autonomy, competence, and relatedness.
   a. **Autonomy:** Autonomy is supported by an interface or task that provides the user with as much choice as is safe and practical in setting immediate and long-term goals and in how he or she performs the task.
   b. **Competence:** Competence is supported by an interface that is intuitive and by task demands that match the skill of the user and provide opportunities for skill improvement.
   c. **Relatedness:** Relatedness is supported by sociotechnical environments that facilitate supportive interaction with other persons and with the technology, that avoid experiences of alienation or isolation of the user from others or from the task, and that engender feelings and attitudes that the technology serves the person, not vice versa.
3. **Self-concordant goals:** The self-concepts and the values (attitudes, beliefs) of the operator should be evaluated as part of the person analysis (Szalma, 2009) so that the technological environment can be shaped to these values to support the achievement of self-concordant goals and to maximize internalized and integrated regulation of task-related behaviors.
4. **Need satisfaction:** Immediate need satisfaction, and the benefits that derive from it, should be considered an *experiential outcome* of the interaction with the technology; need *dissatisfaction* may motivate use of the technology. User experience will be enhanced when the task or interface conforms to the above principles.
5. **Organizational context:** For complex operational environments, an interface may support short-term need satisfaction, but sustained, long-term need satisfaction will occur only if the factors that support them are also incorporated into the broader sociotechnical system.

multiple levels, ranging from the sociotechnical system to the design of display and control elements (for a general hierarchical perspective on SD-theory, see Vallerand, 1997). Table 2 lists factors that previous SD-theory research has identified as facilitating or thwarting need satisfaction and that may extend to human–technology interaction. Table 3 provides a list of example questions to consider in designing technology or a task to support intrinsic or autonomous extrinsic motivation.

In general, the major goal for motivational design should be to reduce the degree to which use of the interface fails to support (or interferes with) need satisfaction and for the technology to instead facilitate need satisfaction. In short, the tool to be used, whether an interface or a training procedure, should be *convivial* (Hancock, 2009; Illich, 1973). It is possible that in some circumstances, technology structured according to the principles of SD-theory may serve as an effective means of satisfying the basic psychological needs in circumstances in which satisfaction of the latter was previously blocked, thereby supporting the general goal of creating technology to improve well-being. That is, use of technology may be motivated by need dissatisfaction, and its use may facilitate satisfaction. Indeed, there is initial evidence for this contention (Sheldon et al., 2011).

However, it is unlikely that all technological environments will facilitate integrated or intrinsic regulation. In these circumstances, creating technology to support identified regulation should be the standard pursued, if not ubiquitously attained. Supporting autonomous motivation to the extent possible can be achieved by identifying the goals of the user in the task context, both the content (the "what") and the reason for selecting the goals (the "why"). If it is

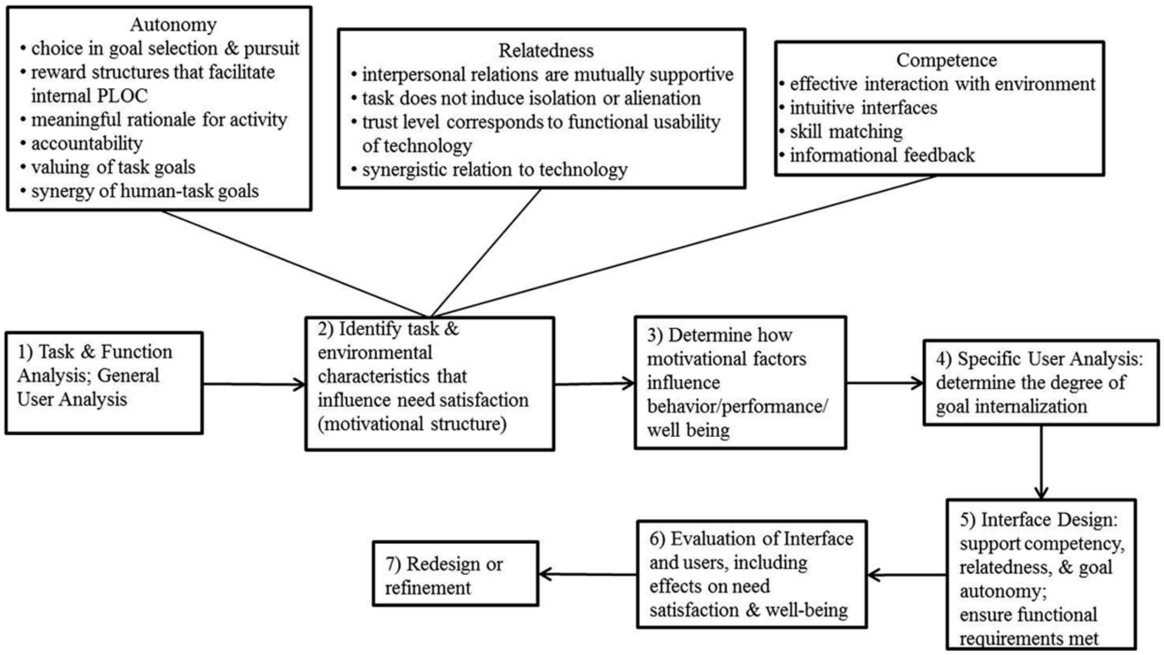

Figure 3. General guidelines for incorporating motivation into technology design (adapted from Szalma, 2009). PLOC = perceived locus of causality.

discovered that components of the task or technology promote external or introjected regulation (or, in the extreme, amotivation with respect to the task; see Figure 1), the relationship between the task or technology and the person's goals should be reevaluated. Specifically, the task, interface, training procedures, and/or selection methods should be redesigned to bring task or system goals into concordance (cf. Sheldon & Elliot, 1999) with the person's goals (in cases of interface/task design) or the person's goals into concordance with task goals (in cases of training/selection). With respect to the latter, when such concordance is achieved via training, it should include procedures to facilitate internalization of task or broader system goals by the person (see Table 2).

General Procedural Guidelines for Motivational Design

Many of the ideas for motivational design presented here are not entirely new to HF/E, and it is very likely that many practitioners consider motivation in their designs. In previous treatments, the focus was on emotion and experiences of pleasure in the interaction with a device. Techniques for eliciting a user's values or goals, such as those described by Olphert and Damodaran (2004), tend to apply methodologies established in business and engineering, such as participatory design and focus groups. These approaches have utility, but they can be augmented by methods used in psychology to identify how the relation of the person to task goals and to the context in which they are pursued affect the person's motivational state. We thus do not need to invent an entirely new set of procedures or methods. We need only incorporate motivational requirements and motivational measures into current practice.

The designer should first seek to discover not only *what* the person wishes to achieve, but also *why* (Hancock, 2009). Answers to both of these questions provide the information necessary to identify a *how* that best fits the person's needs, relative to both the technology use itself and to his or her psychological needs for autonomy, competence, and relatedness. In other words, this approach requires extending our consideration of system requirements to include structures that support the experience of autonomy and competence in technology use that, at least, does not undermine relatedness. It means considering not only utilitarian or hedonic goals but

TABLE 2: Factors That Affect the Experience of Need Satisfaction and Internalization of Task Goals

Facilitating Need Satisfaction	Thwarting Need Satisfaction	Promoting Internalization
• Choice in setting goals and selecting paths to achieve them • Information demands are intrinsically interesting or, if extrinsic, are organized to support autonomous decision making	• Lack of choice	• Meaningful rationale for task
• Informational feedback is experienced as autonomous (self-determined) and associated with an internal perceived locus of causality rather than as externally controlled	• Controlling feedback; an external perceived locus of causality	• Emphasis on choice rather than on control
• Accountability for performance outcomes is experienced as autonomous rather than controlled (e.g., surveillance may undermine self-determined motivation)	• Tangible rewards experienced as controlling	• Participation in goal selection and planning
• Skill development opportunities	• Performance-contingent rewards	• Participatory ergonomics
• Learning goals	• Performance goals	• Acknowledgement that task may be uninteresting
• Acknowledging the person's inner experiences related to the activity	• Skill atrophy	
• Supportive interpersonal relationships	• Social pressure	
• Experience of connectedness with the technology and the task	• Time pressure • Threat	
• Development and maintenance of a level of trust in the technology that corresponds to its functional usability	• Surveillance • Evaluation • Deadlines • Isolation, alienation • High information retrieval costs	

Note. These are not intended as exhaustive lists. Rather, they represent factors identified by self-determination theory research that have been found to affect need satisfaction or goal internalization in a variety of contexts but applied here to human–technology interaction.

also goals related to integrated and identified regulation.

Figure 3 illustrates sequential steps for including motivation in the design process. Incorporating motivational design principles into HF/E requires analysis of both the task and the person. HF/E already possesses the tools to incorporate motivation into design, in a manner analogous to that for inclusion of individual differences into design principles (Szalma, 2009). Part of the process of a task analysis involves identifying the perceptual and cognitive demands (more broadly, the "characteristics") of the system or task. The person analysis should include stable cognitive and affective traits (Szalma, 2009) but also immediate and long-term goals and the degree to which the goals are internalized or integrated with the self (i.e., self-concordant). Incorporation of motivational structures into the process simply requires, in addition to analyses of task characteristics and the population of users, that one also includes in the task analysis the motivational structure of the context and that the user analysis includes evaluation of the degree of goal internalization and human–task goal concordance. The task can then be structured in a manner that

TABLE 3: Example Questions to Consider When Designing Technology to Support Identified, Integrated, or Intrinsic Motivation

Need	Example Questions
Autonomy	• Do users feel that they are in control of the activity or that the technology controls them? • Do users experience choice in activities and in goal selection and pursuit, without information overload? • Are the goals for the technology or the task internalized and integrated with the self of the user? • Are short-term hedonistic goals supportive of long-term psychological well-being (eudaimonic goals)?
Competence	• Is the interface easy to use? • Does the interface support skill development and maintenance? • Does the technology support prevention of skill atrophy? • Does the technology facilitate active engagement of the user in personally relevant and "optimally" challenging activities?
Relatedness	• Do individuals feel alienated when they use the technology, as if they are a "cog" in the system, or do they feel meaningfully related to their work, their colleagues, or their supervisors? • Does interaction with the system increase feelings of connectedness, or does it increase feelings of aloneness or alienation? • Do users tend to abandon responsibility for the task or technology? • Does the interface support secure or insecure attachment with others? • Does the interface support high-quality relationships (intimacy) or low-quality relationships (aloneness)? • Does the technology help support only material goals, or does it also support nonmaterial goals?

maximizes to the extent practicable the number of self-concordant task goals as well as activity that is experienced as autonomous and competence supporting.

A first step is to identify task goals and how their attainment is constrained by context, including the interface or task itself and the goals of the users (Steps 1 and 2 in Figure 3). Then identify for each task element how that element supports (or does not support) identified or integrated regulation (Steps 2, 3, and 4 in Figure 3). This process may be as simple as increasing the salience of cues relating the task elements to a broader, highly valued goal or, in some settings, introducing variability into the work that alleviates the boredom and low-autonomy characteristic of many work environments or, in other settings, redesigning the interface to be inherently interesting to the person. Broad interest inventories may not be sufficient in some cases, if the task element is in the time frame of seconds (i.e., immediate activity). One may need to evaluate both general and context-independent interests as well as the person's immediate context-dependent interests during task performance.

Satisfaction of the three basic needs may serve as criteria for evaluation of task elements. If a task is discovered to be monotonous, then interventions may include adjustment of operator autonomy based on task load, activities that facilitate competence building in the domain, and self-concordant activities to engage the operator during periods of low task load (based on goal internalizations identified in Step 4 of Figure 3). Note that the objective should not necessarily be to induce maximum autonomous motivation at all times, as such an outcome is unrealistic in many circumstances. Rather, the objective should be that even when the *task* is not engaging ("motivating") the *person* may be engaged because of the broader, contextualized meaning the task has for his or her self-concordant goals. This goal is more than achieving "buy-in" or providing operators with "ownership" over their activities. The facilitation of these needs, and the subsequent emergence of internalized or integrated motivation, must be manifested in the design of the task or technological environment itself.

For each component of a task/interface, the questions to be addressed include the following: (a) How do the goals for this activity relate to the user's goals? (b) How does the activity affect the user's experience of autonomy and competence? (c) Does the activity facilitate connectedness or does it alienate the person from his or her broad internalized and integrated (i.e., highly valued) goals? (d) Do the person's integrated goals conflict with overall (external) task goals? If so, then one of these should be changed: the task goal whenever possible. If task goals are brought in line with the person's integrated goals, then (e) how does the combination of task elements within an activity affect the person's experience of competence and autonomy? Does the person experience the task as internalized or integrated regulation, that is, meaningfully related to his or her self-concordant goals?

Assessment of motivation. A challenge for any application of motivation theory to HF/E is in the assessment of user motivation. Measures of specific (contextually based) and general (personality-based) need satisfaction are necessary. Fortunately, well-validated measures exist and are easily available (e.g., http://www.selfdeterminationtheory.org/questionnaires). There are also behavioral methods for assessing autonomy (e.g., the "free choice" method; see Deci & Ryan, 1985). Assessment of need satisfaction using these measures should therefore be a routine part of interface/task analysis (Steps 2 through 4 in Figure 3) as well as in follow-up assessments after implementation (Step 6 in Figure 3).

At Step 6, one can also measure derivative outcomes of motivation that are relevant for human–technology interaction, such as stress, workload, and fatigue, as well as the TAM constructs of perceived ease of use and perceived usefulness (for measures of the latter, see Davis et al., 1992; Venkatesh, 2000). These measures should be used in tandem with measures of motivation rather than as proxies for assessing motivation.

The futility of unethical application. Designing technology, tasks, or training procedures to induce a person to internalize system goals can result in improved performance and user well-being, but motivational principles also have the potential for abuse by managers or designers (cf. Parasuraman & Riley, 1997). For instance, designers or managers may attempt to induce individuals to internalize goals by using these principles to create persuasive propaganda or manipulative interventions. However, practitioners seeking to abuse the principles of motivational design are forewarned that it is not only unethical to do so, but it will also be ineffective. The only way to achieve integrated or identified regulation is to *actually* satisfy the three basic psychological needs. That is, the technological context must support actual autonomous behavior, the development and maintenance of actual competence, and actual, genuine relatedness. Attempts at (external) manipulation will lead, at best, to introjected regulation and the resultant motivational costs to usability and performance.

SUMMARY AND CONCLUSIONS

The main goals for this paper were (a) to describe a general theoretical model of how motivation influences human–technology interaction, based on SD-theory, and (b) to incorporate this theory into general principles and guidelines for motivational design. There has been a very limited number of empirical studies investigating the influence of motivational characteristics of technology on human performance and well-being, and no published studies have explicitly integrated SD-theory into research on HF/E principles or in their application to design. This work represents a crucial next step if we are to create technology to enhance human well-being. However, one cannot measure or evaluate something unless one is aware of its importance. The motivational design principles and general procedural guidelines described here are therefore intended to alert designers to concerns, such as autonomy, so that they will be more likely to include assessment of them in their design processes. These principles are meant to augment the established principles of human factors design. To the extent that the principles and procedural guidelines described here are already used in "real-world" practice, this paper represents a theory-based specification of what has to date been accomplished informally but not articulated in the HF/E literature. If this is the case, it is hoped that these principles will serve to close a gap between HF/E theory and actual practice.

Technology can be an effective tool for improving well-being by facilitating the satisfaction of basic human needs for autonomy, competence, and relatedness. Alternatively, it may also be designed (implicitly or explicitly) to thwart the experience of need satisfaction and thus prevent well-being. HF/E, as a discipline, will contribute to one of these outcomes. The principles and guidelines described in this paper are intended to facilitate the former in order to prevent the latter.

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KEY POINTS

- Motivation theory and research are relevant to human–technology interaction, but they have been mostly neglected in human factors and ergonomics research and practice.
- Self-determination theory describes motivational structures and processes that can be adapted for inclusion into principles and guidelines for the design of technology.
- A theoretical model of motivation and human–technology interaction was described, and general principles and guidelines for motivational (eudaimonic) design were proposed.
- Autonomous motivation for technology use will occur if the technology facilitates satisfaction of the basic psychological needs for autonomy, competence, and relatedness.
- Technology that enables autonomous behavior, effective (competent) engagement with the task, and a sense of connectedness (relatedness) with others via the technology will increase the likelihood of identified or integrated extrinsic motivation or, in some circumstances, intrinsic motivation.
- A crucial determinant of the motivational experience with technology does not derive from the task goal per se but from whether the appraised progress toward goal attainment supports the experience of satisfaction of the three basic psychological needs.
- Problems of motivation in human–technology interaction can be addressed by including an evaluation of motivational characteristics of the task, the interface, the context, and the relationships of these to user motivation as part of task and user analyses.

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