The Technology Integration Model (TIM). Predicting the Continued Use of Technology.

Abstract

The human-computer relationship is often convoluted, and despite decades of progress, many relationships relating to continued use are unclear and poorly defined. This may be due to a lack of interdisciplinary collaboration, especially from a theoretical standpoint between computer science and psychology. Following a review of existing theories that attempt to explain continued technology use, we developed the Technology Integration Model (TIM). In sum, the main objective of TIM is to outline the processes behind continued technology use in an individual's everyday life. Here we present the model alongside a description of its scope and the relationships between constructs. This can help generate research questions relating to technology use while simultaneously addressing many previous shortcomings of existing models. As a unifying theory, TIM can quickly be adopted by researchers and developers when designing and implementing new technologies.

Key Words: *Technology Use; Continued Technology Use; Extended Self; Technology Integration Model.*

Abbreviations: TIM – Technology Integration Model, TAM – Technology Acceptance Model.

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1. Introduction

1.1. Developing a new theory of technology use.

It has become increasingly important to understand the relationship people have with technology. Many positive effects have arisen from technology use such as social inclusion, increased access to information, assistance with every-day tasks, and healthcare applications (Andrade & Doolin, 2016; Khosravi, Rezvani, & Wiewiora, 2016; Kirkpatrick, 2016; Piwek, Ellis, Andrews, & Joinson; 2016). In contrast, negative side effects such as technology addiction, perceived privacy breaches, reduced physical activity, online shaming and unsatisfactory work-life balance remain widespread (Akdemir, Vural, Çolakoğlu, & Birinci, 2015; Bergström, 2015; Clayton, Leshner, & Almond, 2015; Jeong, Kim, Yum, & Hwang, 2016; Klonick, 2016; Mamonov & Benbunan-Fich, 2014; Osiceanu, 2015; Schoneck, 2015; Steijn & Vedder, 2015). At the same time, technology rapidly develops and adapts, with current trends suggesting a dramatic increase in the number of everyday objects that connect to the internet (e.g. the internet of things) (Bergman, 2015). Yet, despite significant and measurable impacts, the relationship between people and technology remains poorly defined from a theoretical standpoint. This hinders the development of new technologies and prevents a fuller understanding of their impact.

In addition, the fundamental reasons behind technology use have often been difficult to define, despite the prevalence of technology in society. Even specific factors which influence or predict future use remain contentious (Karahanna, Straub & Chervany, 1999; Ding, Chai & Ng, 2012). However here, through the evaluation of previous theoretical models, we propose a new integrated theory of continued technology use and technological impact.

Theoretical and empirical work often struggles to keep up with the speed of technological development, however the research remains essential when attempting to predict subsequent successes and failures. Continued use may indicate the potential life cycle of a developed technology and it is possible that by measuring technology use, we can explore applications that benefit many stakeholders including end-users, developers and retailers of technology. For example, those who develop and sell technologies will need to obtain customer satisfaction through adequate and beneficial use if they wish to obtain a large and loyal consumer base. Furthermore, encouraging the use of quality of life technologies, such as health monitoring devices, can increase the positive impact of the intervention. The exploration of continued use may increase our understanding of technology use habits, a variable which can both prevent and encourage behavioral change. Technology is often developed to improve lifestyles but whether these benefits are realised depends on the way in which they are used.

1.2. Existing Theories

As the applications of studying technology use span widely, there has been a shift in the literature from measuring technology adoption to measuring technology use (Ding, Chai & Ng, 2012). Often, the continued use of a technology is seen as an extension of the adoption process, suggesting both adoption and post-adoption behaviors can be measured using the same variables (Davis, Bagozzie, & Warshaw, 1989; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016). The most popular theory that predicts technology adoption and future-use is the technology acceptance model (TAM) (Marangunic & Granic, 2015). TAM contains several variables such as perceived usefulness, perceived ease of use, external variables, attitude and behavioral intention as precursors of technology adoption and use (Davis, Bagozzie, & Warshaw, 1989). However, the variables which predict technology adoption have been shown to differ from the variables which predict continued technology use (Limayem, Cheung & Chan, 2003). For example, a person's attitude towards a technology before adoption is often influenced by perceptions of usefulness, ease of use, result demonstrability, visibility and trialability, whereas attitudes after adoption are influenced by instrumental beliefs of usefulness and perceptions of image enhancements (Karahanna, Straub & Chervany, 1999). As such it appears that continued technology use is not just a continuation of technology adoption, but a phenomenon within itself. This raises additional questions regarding the suitability of TAM and successive extensions when measuring continued use.

After citing the original TAM model, many researchers simply extend it by including additional variables of their own choosing, which they perceive to have particular relevance to the technology being assessed. (Jafarpour, 2016; Ooi & Tan, 2016; Ramos-de-Luna, et al., 2016; Tsai, Chang & Ho, 2016; Wang & Sun, 2016; Yoon, 2016). This can make subsequent generalization difficult and a 2007 meta-analysis generated a list of 78 external variables that had been added to TAM with the aim to predict perceived ease of use and perceived usefulness across various contexts (Yousafzai et al., 2007a). Examples of these included *'Screen Design'*, *'Management Support'*, *'Organizational Policies'*, *'Cognitive Absorption'*, and *'Cultural Affinity'* (Yousafzai et al., 2007a). There is no coherent trend regarding which variables are included in these models. Consequently, the reliability of variables cannot be assessed due to a lack of succeeding confirmatory research. The development of any new theory must therefore be inclusive of key constructs which predict the use of current and future technologies. In turn, this will also become a platform for researchers to re-test the same concepts and improve our understanding of continued technology use.

1.3. Theoretical Unification

Several theories of continued use describe a set of variables which predict technology adoption, and then include additional variables to the initial model to explain continued use (Setterstrom, Pearson & Orwig, 2013; Kim & Crowston 2011). Others consider continued use in isolation as its own behavior (Bhattacherjee, 2001; Limayem, Cheung & Chan 2003). A theoretical unification approach (Venkatesh, Morris, Davis & Davis, 2003) was chosen to generate a new model (Figure 1). This acknowledges both existing work and evidence that can contribute to our understanding of continued technology use. However, merging existing theories can sometimes lack the novelty required to provide new research directions that expand our knowledge. Therefore, we aimed to merge competing theories into a singular comprehensive model of technology use and impact, whilst incorporating psychological constructs which have never been considered in existing technology use models. What makes the current unification different from previous attempts including the UTAUT, UTAUT2 and the Multilevel Framework of Technology Acceptance and Use (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016), is its retained parsimony, its focus on technology use rather than adoption, and the inclusion of novel insights which describe the impact that technology has on people. To inspire the new model, key groups of variables will be identified across existing technology use theories. A novel variable called extended-self is introduced, which is proposed to predict continued technology use (Steinhart, 2015; Belk, 1988, 2013; Clark & Chalmers, 1998). The scope of new model is then defined, presented and discussed in detail.

2. Review of Existing Literature

2.1. Key Predictor Variables

To identify key themes, 11 models of continued technology use were reviewed (Table 1). We did not include models that only predicted technology adoption, as the aim was to understand continued use beyond initial adoption. Numerous variables have been proposed to influence continued use such as satisfaction, habits and affective reaction (Bhattacherjee, 2001; Limayem Cheung & Chan, 2003; Kim & Crowston, 2011). Some variables across models are synonymous or could be grouped in a more general construct, allowing for consistent testing. This permits the generation of key themes or groups of variables. The purpose of this is to provide a summary of existing salient ideas which predict technology use, that can be used in the development of future theories. Overall, 14 key variables reside across models (Table 1). Therefore, it is possible to create a new and comprehensive model of technology use, by taking inspiration from these key themes.

Table 1: Identification of key technology use variables by combining synonymous variables across models.

Key Theme	Variables Included	Link
Ease of Use	Effort Expectancy (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012), Perceived Ease of Use (Kim & Malhotra, 2005; Davis, Bagozzi & Warshaw, 1989; Venkatesh & Davis, 2000), Objective Usability (Venkatesh and Bala, 2008) and Technicality (Setterstrom, Pearson & Orwig, 2013).	Effort, ease or difficulty of performing a technology use behavior.
Pre – Use Evaluations	Attitude (Kim & Crowston, 2011; Davis, Bagozzi & Warshaw, 1989), Performance Expectancy (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012), Perceived Value (Setterstrom, Pearson & Orwig, 2013) and Result Demonstrability (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008).	Evaluating the technology before use.
Behavioral Intention	Behavioral Intention (Kim & Malhotra, 2005; Davis, Bagozzi & Warshaw, 1989; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016) and Continuance Intention (Limayem, Cheung & Chan, 2003; Setterstrom, Pearson & Orwig, 2013; Bhattacherjee, 2001).	A person's intentions to use the technology
Technology Use Behaviors	System Use (Kim & Malhotra, 2005; Davis, Bagozzi & Warshaw, 1989), IS Continuance (Limayem, Cheung & Chan, 2003) and Use Behavior (Venkatesh & Davis, 2000; Venkatesh, Thong & Xu, 2012).	Actual technology use.
Context	Environmental Attributes, Location Attributes, Events(TIME) and Organisational Attributes (Venkatesh, Thong & Xu, 2016).	Contextual factors that could influence use.
Support	Perceptions of External Control (Venkatesh & Bala, 2008), Facilitating Conditions (Venkatesh, Thong & Xu, 2012; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2016), and Organisational Attributes (Venkatesh, Thong & Xu, 2016).	Support mechanisms available, which could aid the use of the technology.
Extrinsic Motivations	Perceived Usefulness (Kim & Malhotra, 2005; Limayem, Cheung & Chan, 2003; Setterstrom, Pearson & Orwig, 2013; Bhattacherjee, 2001; Davis, Bagozzi & Warshaw, 1989; Venkatesh & Davis, 2000), Job Relevance (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008), task attributes (Venkatesh, Thing & Xu, 2016) and Objective Usability (Venkatesh & Bala 2008).	Practical advantages of using the technology to complete specific tasks.

Table 1 Continued: Identification of key technology use variables by combining synonymous variables across models.

Key Theme	Variables Included	Link
Intrinsic Motivations	Enjoyment (Setterstrom, Pearson & Orwig, 2013), Uncertainty Avoidance (Setterstrom, Pearson & Orwig, 2013), Affective Reaction (Kim & Crowston, 2011) Perceived Enjoyment (Venkatesh & Bala, 2008) and Hedonic Motivations (Venkatesh, Thong & Xu, 2012).	Internal experience that is the result of using the technology.
Habit	Repeated Behavioral Patterns (Kim & Malhotra, 2005) and Habit (Limayem, Cheung & Chan, 2003; Setterstrom, Pearson & Orwig, 2013; Kim & Crowston 2011; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016).	Habitual mechanisms which drive technology use.
Individual Differences	Experience (Venkatesh & Davis. 2000; Venkatesh & Bala, 2008; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu), Computer Self Efficacy (Venkatesh & Bala, 2008), Computer Anxiety (Venkatesh & Bala, 2008), Computer Playfulness (Venktesh & Bala, 2008), Gender (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012), Age (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012) and User Attributes (Venkatesh, Thong & Xu, 2012).	Attributes of the user which may influence the use of a technology.
Post-Use Evaluations	Feedback Mechanisms (Kim & Malhotra, 2005) Sequential Updating Mechanisms (Kim & Malhotra, 2005), Confirmation (Limayem, Cheung & Chan, 2003; Bhattacherjee, 2001), Satisfaction (Limayem, Cheung & Chan, 2003; Bhattacherjee, 2001), Cognitive Reaction (Kim & Crowston, 2011) and Output Quality (Venkatesh & Bala 2008; Venkatesh & Davis, 2000).	Evaluating the technology after use, which may influence future behavior.
Price	Perceived Fee (Setterstrom, Pearson & Orwig, 2013) and Price Value (Venkatesh, Thong & Xu, 2012).	Monitory costs associated with using the technology.
Social Factors	Subjective Norms (Kim & Crowston, 2011; Venkatesh & Davis, 2000; Venkatesh & Bala, 2008), Image (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008) and Social Influence (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012).	A user's perceptions of how others view them if they were to use the technology.
Mandatory Use	Voluntariness (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008; Venkatesh, Morris, Davis & Davis, 2003).	If the user perceives using the technology to be mandatory.

2.2. Additional Variable: Self-Extension

What remains absent in existing theories is an explanation of the core human-technology relationship. Without this, there is a large conceptual gap because scholars have ignored how technology and humans interact in a rudimentary manner. This is important to define as it can lay the foundations to explain more complex and abstract technology use behaviors. Specifically, self-extension has repeatedly been shown to be important when it comes to explaining the psychological impact relating to the ownership of traditional goods and digital services (Sheth & Solomon, 2014).

Stone tools were invented by our solution seeking homo habilis ancestors 2.5 million years ago (Mazur, 2002), and tool use suggests that human nature is inherently ‘cyborg’ as primitive technology can extend a person’s physical capabilities, and is not a phenomenon constrained to science fiction (Wells, 2014). This is the core concept behind self-extension via technology use, as technology, possessions, and tool use extend who we are as humans and people (Steinhart, 2015; Belk, 1988, 2013; Clark & Chalmers, 1998). The part of the human to be extended varies across previous theories as the mind (Clark & Chalmers, 1998), body (Steinhert, 2015) and identity (Belk, 1988, 2013) have previously been argued to be extended through using and owning objects. Recent evidence suggests that mobile phones can extend a person’s self-identity, as personality traits can be predicted from smartphone choice (Shaw, et al. 2016). Tool use has been shown to extend our physical body schema; our neuronal representation of our body size, shape, location and movement in environmental space (Iriki, Tanaka, & Iwamura, 1996). Smartphones have been shown to extend cognitions, as those who think more intuitively and less analytically when solving problems are more likely to use their smartphone in everyday situations to retrieve information (Barr, Pennycook, Stolz, & Fugelsang, 2015).

The variable 'Extended Self' has received growing attention since originally proposed by Belk (1988) (Schultz, 2014). By describing how people feel a claim and ownership over objects, extended self-ideas depict the core relationship between the technology and the owner which no other variable in the review encapsulates. Participants have self-reported that mobile phones are important to their self-identity, and stated that their phone extended them less when separated from their phone, in comparison to when their phone was in their possession (Clayton, Leshner & Almond, 2015). This variable is unique because it suggests there is a key psychological amalgamation to a technology in a user's possession, that has yet to be applied to technology use. This could, in turn, provide new insights in terms of how self-extension via technology use carries over into continued usage.

3. Theoretical Construction

3.1. Scope

Unification models can easily become a “jack of all trades” in an attempt to explain all factors that lead to the phenomenon under investigation (Venkatesh, Thong & Xu, 2012). However, insights are often diluted across many variables which can negatively impact understanding of the described phenomenon (Venkatesh, Thong & Xu, 2016). Thus, the focus of this new theory is to describe factors which influence an individual user when predicting technology use. Explaining the spread of technology in an organization or a specified society will not be considered in this model due to the expanse of variables which would need to be incorporated. This topic would require a separate sociological model. However, context here will concern a person’s immediate surroundings including their current location.

The new model (Figure 1) is entitled the Technology Integration Model (TIM) and the main objective of TIM is to outline the processes behind continued technology use in an individual’s everyday life. TIM examines how technology integrates with its user over time via the model iterating repeatedly until the technology is abandoned or replaced. The constructs in TIM predict technology use in the few moments before a technology is used/not used. This is advantageous as we do not aim to predict intentions or attitudes towards using the technology, but aim to predict the precursors of actual behavior. TIM describes the use-cycle of a singular technology. It is likely that a user will have several technologies at a time and thus, will have one predictive use-cycle for each of their devices.

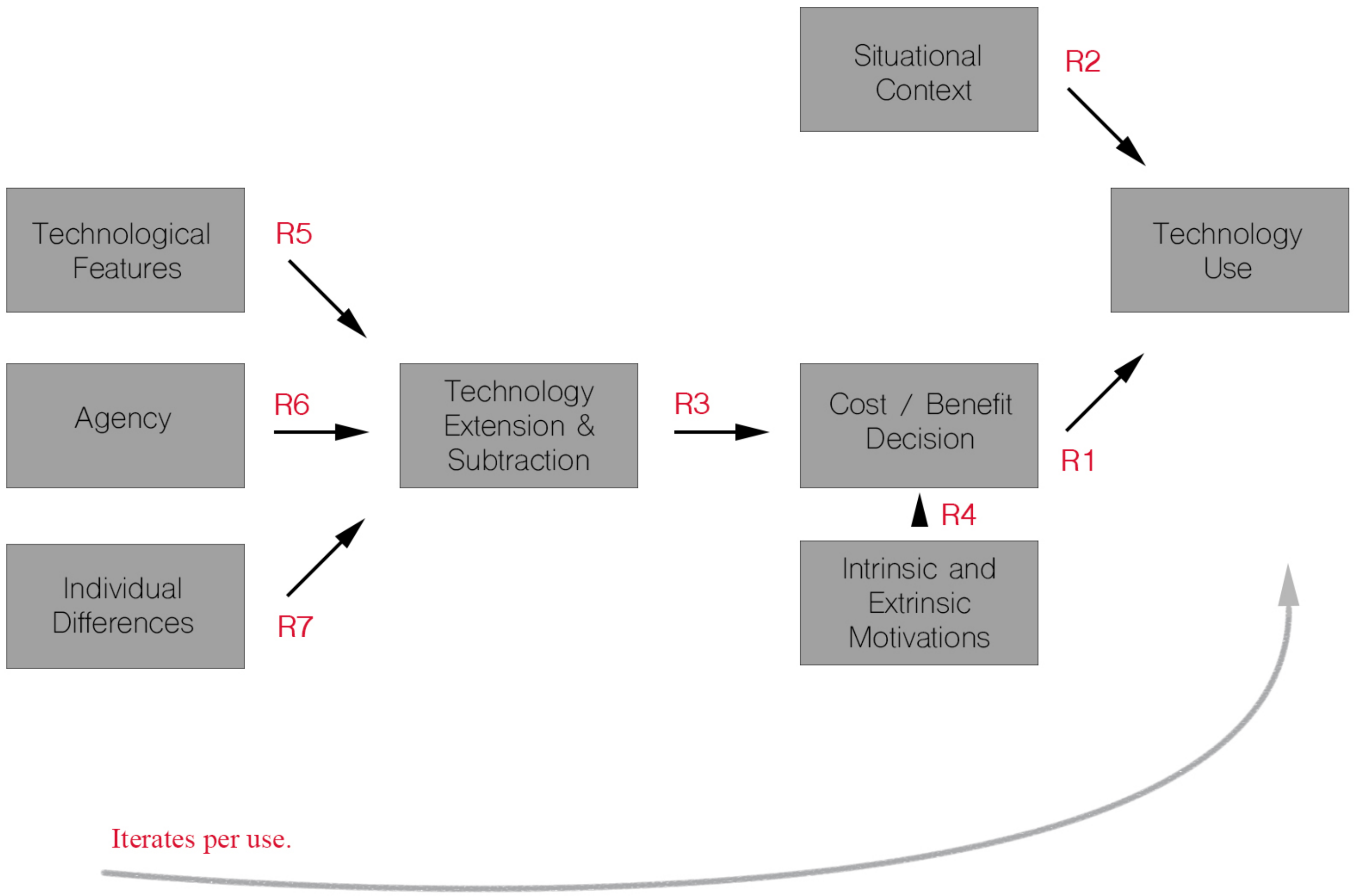

Figure 1: The Technology Integration Model (TIM).

3.2. The Technology Integration Model (TIM)

The previous literature review and the exploration of a new variable, extended-self (Belk, 1998), has inspired the creation of The Technology Integration Model. TIM proposes that they are two direct predictors of technology use, which are, a *cost-benefit decision (R1)* and *situation context (R2)*. This is because when the decision to use a technology becomes less conscious, use is prompted by contextual cues (Stawarz, Cox & Blandford, 2015). Over time it is proposed that the more a technology becomes habitual through repeated use, *situational context* will become more predictive and the *cost/benefit decision* will become less predictive of technology use. This allows us to understand how technology use can become habitual. Collectively, habit and perceived value which are two variables related to *situational context* and the *cost-benefit decision*, have previously been shown to explain 71% of the variance in continued use of a web-enabled wireless technology (Setterstrom, Pearson & Orwig, 2013). Therefore, there is already strong empirical evidence to suggest that the combination of *cost/benefit decision* making, and technology use in response to habitual cues such as *situational context* will be able to explain a large proportion of technology use variance.

TIM continues to describe what influences the *cost-benefit decision*, namely, *technology extension & subtraction (R3)* and *intrinsic & extrinsic motivations (R4)*. Thus, if a technology adds affordances to a person, which helps satisfy their intrinsic and extrinsic motivations, it will be considered worth using, prompting use. Finally, TIM discusses what predicts *technology extension and subtraction*, to help understand the positive and negative effects technology can have on a user. Overall TIM has eight variables including *technological features, agency* and *individual differences* which are shown in Figure 1 as predictors of *technological extension and subtraction (R5, R6 & R7 respectively).* All relationships are currently described as connections as research is needed to determine whether they are moderating or mediating relationships. The development and precise definition of the variables in TIM are outlined in the following section.

3.3. Variable Development

By focusing on technology use separate from adoption, it is possible to isolate variables that predict subsequent usage. This facilitates the creation of a more parsimonious model, when compared to previous theories that attempt to combine both, such as the Unified theory of Technology Adoption and Use (UTAUT), the UTAUT2 and the Multi-Level Framework of Technology Acceptance and Use (Venkatesh, Morris, Davis & Davis, 2003; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016). The variables defined in TIM have been chosen from the key themes review (Table 1) and adapted due to their relevance when considering the scope of the model (section 3.1.). The following section will outline the development of the constructs included in the new model.

3.3.1 Technological Features

Existing technology use models rarely focus on features that a technology contains. Only the Multi-level Framework of Technology Acceptance and Use, deemed this important (Venkatesh, Thong & Xu, 2016). Their variable, Technology Attributes, emphasises how the overall functions, characteristics and features of a technology plays a role in continued technology use. (Venkatesh, Thong & Xu, 2016). TAM vaguely describes how the features of a technology influence technology adoption and use by stating that a technology's perceived ease of use predicts the behavioral intention to use the technology (Davis, Bagozzi & Warshaw, 1989). However, this appears oversimplified, and ignores the description of useful features, which could be included in the design of technology. For example, one study asked information system researchers their opinion on TAM, with one participant stating that *"TAM's simplicity makes it difficult to put into practice … imagine talking to a manager and saying that to be adopted, technology must be useful and easy to use"* (Lee, Kozar & Larsen, 2003, p. 766). Therefore, the formation of the variable *Technological features* aims to provide descriptive knowledge which can be used to guide the design and implementation of technology. Arguably a theory of human-computer interaction must incorporate both human and technological feature variables that may influence the use of technology.

Technology Features are therefore defined here as a technology's hardware, and software properties. Technologies have a large array of features, for example: input modality, visual display, device connectivity, sensors, sharing features, device interactivity with the environment, storage, ergonomics, build material and engineered physical movement etc. The features a technology may possess will change as technology advances, and therefore, this construct is required to have a wide scope to ensure it stays relevant for future technology. This differs slightly from the definition of Technology Attributes (Venkatesh, Thong & Xu, 2016) as the functions of a technology are described in a separate variable, *technology extension and subtraction.*

3.3.2. Agency

Agency has been defined as "the experience of controlling both one's body and the external environment" (Limerick, Coyle & Moore, 2014). However, feelings of control also resonate in several synonymous technology use variables such as effort expectancy, perceived ease of use, and technicality (Davis, Bagozzi & Warshaw, 1989; Venkatesh & Davis, 2000;

Venkatesh, Morris, Davis & Davis, 2003; Kim & Malhotra, 2005; Venkatesh. Thong & Xu, 2012; Setterstrom, Pearson & Orwig, 2013). Whilst referring to the effort, ease or difficulty of performing a technology use behavior, it is possible that core to all these variables is the idea of *agency* over the technology we use, as issues with usability leave the user with a lack of control over the technology. A recent review confirmed that a feeling of *agency* is fundamental when encouraging human-computer interaction. Limerick, Coyle, & Moore (2014) discusses concepts such as intentional binding, gulf of execution, system reliability, system feedback, latency, task automation and embodiment which can affect the feelings of *agency*. These concepts are reminiscent of the criterion proposed for a technology to extend a person's mind which include: trust, accessibility, reliability and availability of the technology (Clark & Chalmers, 1998). As this theory focuses on human-computer interaction as a new direction when comprehending technology use, it is deemed important to include agency in the model, as it may explain previous findings concerning why ease of use predicts system use and technology usage intentions (Yousafzai, Foxall & Pallister, 2007b). Finally, significant to the extension of self-theory is a sense of *agency* over the technology we use (Belk, 1988, 2013). This idea was first proposed by McClelland (1951) who stated that the more control you exert over an object or technology, the more incorporated an object becomes part of a person's self-identity.

3.3.3. Individual Differences

Individual differences can include personality traits, demographics and other variables that can be used to describe the end user. Other examples might include a person's time management, mental & physical health, cognitive functioning, skills, mood, age, personality, social relationships, social economic status, occupation, culture, wealth and environment.

Shneiderman & Plaisant (2004) discuss how "all design should begin with an understanding of the intended users, including population profiles" (p. 67). Furthermore, people learn, think, and solve problems through varying methods and will prefer certain types of technology over others (Shneiderman & Plaisant, 2004). Consequently, understanding a user by analysing their *individual differences* is pivotal. *Individual differences* have appeared in a variety of forms throughout existing models through the variables: experience, computer self-efficacy, computer anxiety, computer playfulness, gender and age (Venkatesh & Davis, 2000; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh & Bala 2008; Venkatesh, Thong & Xu, 2012)

The most recent model reviewed, 'A Multi-level Framework of Technology Acceptance and Use', merged the moderating effects of age, gender and experience into a singular variable called 'User Attributes'. This was the result of researchers extending the Unified Theory of Acceptance and Use of Technology to encompass more demographics (Venkatesh, Thong & Xu, 2016). As a result, the model was more flexible and included other demographical variables such as occupation and user type (e.g. employee, consumers and citizens) Whilst the construct *individual differences* may be considered broad in nature, it is possible to repeatedly test the hypothesis that *individual differences* influence technology use (or in TIM technological extension and subtraction), regardless of the *individual difference* under investigation. As a result, researchers are not required to expand the constructs in the model due to a lack of comprehensiveness. The advantage of exploring a wide range of *individual differences* is that it becomes possible to discover which are the most important and influential when predicting technology use, and does not place boundaries on the vast number of *individual differences* that can be included. This will aid the current theory to be generative in future research.

3.3.4. Technology Extension and Subtraction

The current model adopts a modified extended self-theory to explain the human-computer relationship. It does this by describing the acts and functions that a technology enables us to do. Technology has been said to extend a person (Steinhart, 2015; Belk, 1988, 2013; Clark & Chalmers, 1998). An affordance "refers to the physical requirements for an action" (Adolph, 1995, p. 734). Technology executes actions by having affordances or features that extend a person's capabilities, possessions and environment. This can allow a person to achieve something which wasn't previously possible without the technological intervention, or can improve previous methods. When designing, or evaluating a technology we should consider four broad categories of extension (see Table 2). It is proposed that technology extends and adds affordances to our mind, body, environment and possessions.

However, it is also important to consider when technology can impede or become a negative influence. Belk (1998) considers how a loss of possessions can have a negative impact on a person's sense of self. Dependant on the unique features of a technology, a feature might block successful technological extension, or even remove affordances from the user. In extreme cases, some features make the benefits of using a technology obsolete and discourage use. For example, early optical character recognition systems were inaccurate in comparison to human reading abilities at recognising words in text (Govindan & Shivaprasad 1990).

Table 2: Descriptions and examples of how technology can extend and subtract from a person's mind, body, environment and possessions.

Extension Category	Extension	Subtraction
Mind	Technology may 'think' for its user i.e. when using a calculator to compute sums, freeing cognitive resources for other tasks. Technology can extend our mental abilities (Clark & Chalmers, 1998); for example, using your smartphone to remind you of certain events can help aid natural memory capabilities. Imagine visualising several ideas in your head verse drawing out your ideas in a mind map on a whiteboard. Both achieve the cognition of formulating ideas, but use different mediums. A person's psychology, i.e. personality and sense of self can also be extended with technology (Belk, 1998).	A technology will not extend its user if it is too difficult to utilise its affordances. Problem solving due to a technology being difficult to use would impose a heavy cognitive load on the user (Sweller, 1988). Smartphone notifications have been shown to interrupt a task and be disruptive (Bowman, Waite, & Levine, 2015) and peoples' working memory capacities, are related to their ability to multitask (Pollard & Courage, 2017). It has also been argued that offloading thinking onto smart-devices causes a new type of cognitive laziness and users may lose the ability to think for themselves (Barr et al., 2015).
Body	There are two types of human-technology bodily amalgamation; technological incorporation (e.g. prosthesis) and technological extension (e.g. tool use) (de Preester & Tsakiris, 2009). Technological prosthesis can be incorporated into our neuronal body-model that represents the anatomical features of a normative body (de Preester & Tsakiris, 2009). The majority of technology fits into the second category and are considered tools that can extend the human organism and lived body (Steinert, 2015). Tools and objects can extend us by extending our body schema (Iriki et al., 1996).	A technology that is too physically demanding or difficult to use will prevent that technology from extending the person and may even subtract from their physical abilities when performing other tasks if all efforts are directed to using the technology. Power tools can cause limb injuries (Ku, Radwin, & Karsh, 2007) and smartphones, tablets and laptops which encourage unnatural upper body movements have been associated with an increase in repetitive strain injury (Christopherson, 2015).
Environment	Technology can provide new environments for a person to percieve and interact. Social networking sites and virtual reality are considered digital environments. Transport can enable you to go to a new location. Technology can provide new aesthetic and sensory stimulation. The mind is an internal environment and technology can create new environments through mental escapism and flow (Calleja, 2010; Csikszentmihalyi, 1990; Kuo, Lutz, & Hiler, 2016).	Technology can damage and reduce the environment by polluting the air and the sky (Colvile, et al. 2001; Falchi, et al. 2011; Sohaili, 2010). Communication in an instant messaging environment satisfies basic social needs less than face to face interactions (Sacco & Ismail, 2014). A product which is un-attractive to the visual, haptic and olfactory senses is likely to discourage use. Different types of environment such as private spaces may be reduced due to advances in technology.
Possessions	When a person receives a piece of technology, whether it be hardware, software or item collecting in games, it gets added to a persons collection. Possession extension concerns how your possesions work together, i.e. a new technology can improve what you currently own. A new technology may also replace a system if it has better affordances than a previous version. Possessions also have monatory value, and thus extend a persons abstract possessions such as wealth.	Obtaining a technology often subtracts from a person's wealth. New technology can also be incompatible with the technology that is already owned. This can lead to a subtraction in affordances if the combination of the two technologies prevents either one from executing its affordances. An example would be incompatible hardware and software. Technology may execute affordances that removes something from a person's possessions completely i.e. computer viruses.

3.3.5. Intrinsic and Extrinsic Motivations

The current model argues that we use technology to satisfy both *intrinsic and extrinsic motivations.* Some motivations are short lived (e.g. complete a singular task), others are ongoing and require maintenance (e.g. the desire to be part of a social group). Thus, people will maintain several motivations simultaneously, but with different levels of saliency. Examples of using a technology for extrinsic purposes include using a technology to manage money, preserve the environment or to improve physical health. Therefore, extrinsic motivations are goal oriented and instrumental (Wu & Lu, 2013). In contrast, intrinsic motivations are described as using a technology because of the desire to have a particular internal human experience, such as joy, pleasure, fear, satisfaction, excitement or pride (Lowry, Gaskin, Twyman, Hammer & Roberts, 2013). Perceived enjoyment has been shown to increase intentions to adopt an online payment system, and has also been shown to be a strong predictor of intended continual use of Habbo Hotel - a virtual, social world (Rouibah, Lowry, & Hwang, 2016; Mäntymäki & Salo, 2011). Accepting that intrinsic motivations play a role in technology adoption and use, the decision to use a technology does not always have to be rational, i.e. when using gambling machines to satisfy feelings of addiction (Gainsbury, King, Russell, Delfabbro, & Hing, 2017). When contemplating reasons for the low retention rates of wearable technologies, it has been proposed that “many wearables suffer from being a solution in search of a problem” and “don’t add functional value” (Piwek, Ellis, Andrews & Joinson, 2016, p. 2). As such, the designed purpose of a technology must therefore satisfy or be perceived to satisfy at least one of the users *intrinsic or extrinsic motivations* if a developer wants to encourage use.

These intrinsic and extrinsic motivations also include social factors such as subjective norms, image, and social influence which are common across technology use models (Venkatesh & Davis, 2000; Venkatesh, Morris, Davis & Davis, 2003; Venkatesh & Bala, 2008; Kim & Crowston, 2011; Venkatesh, Thong & Xu, 2012). They collectively refer to a user's perceptions of how others view them if they were to use the technology. However, social factors do not have to be considered separately from a person's motivations. Workman (2014) describes in a literature review how humans have a need for experiencing relatedness, which is the need of belonging and being connected with others. The need to belong has been proposed to explain why people use social media such as Facebook (Nadkarni & Hofmann, 2012). Workman (2014) further describes that when technology satisfies this need, a person's intrinsic motivation to use that technology may increase and encourage them to use this further. As a result, social factors appear to be an influential mechanism when understanding the continued use of a technology, however, this does not require a separate construct from other types of human motivation.

3.3.6. Cost Benefit Decision

Existing technology use models posit that behavior is consciously driven from beliefs, attitudes, and other evaluative assessments such as 'performance expectancy' (Venkatesh, Morris, Davis & Davis, 2003). More recently, 'value-based' research models have been applied to technology use, whereby the variable, 'perceived value' examines the utility of technology, based on trade-offs between the perceived benefits and costs (Setterstrom, Pearson & Orwig, 2013) and has been shown to be predictive of intention to use (Hong, Lin & Hsieh, 2017; Cocosila & Igonor, 2015). Measuring *cost-benefit decisions* is advantageous because the outcome of this assessment is a choice to use the technology or not, and is conceptually more of a direct precursor to technology use than ‘behavioral intention’. Setterstrom, Pearson & Orwig (2013, p .1143) stated that “perceived value increases as either the benefits from product consumption increase or the costs associated with consumption decrease”. Therefore, perceived value has enhanced empirical falsifiability when compared to related constructs such as attitudes, as the formation and structure of attitudes are still being explored and debated in the literature (Hogg & Vaughen, 2008). Consequently, the most effective method of capturing a person’s opinion of the technology, prior to use, is through their assessment of costs and benefits, and the consequence of this decision is immediately observable through either use, or no use of the technology.

In TIM, the process of technology extension and subtraction is an interplay between how a technology adds and removes affordances from its user. However, whether it is perceived to cost or benefit the user will depend on whether this extension/subtraction is in line with a person’s motivations. A technology will be perceived to benefit its user if its features increase the ability for a person to satisfy their motivations. A technology will be perceived to cost the user if its features deduct from the ability to satisfy their motivations. As technologies will most likely have both additive and subtractive features, the user will weigh up whether the technology is worth using. Overall the outcome of this decision-making process is binary (worth or not worth using in that instant), and if positive will prompt use.

3.3.7. Situational Context

When the decision to use a technology becomes less conscious, use can also be prompted by contextual cues such as location, existing routine, events, objects, or proceeding actions (Stawarz, Cox & Blandford, 2015). Contextual factors such as being in a hurry or long queues have been shown to have a direct positive effect on intention to use a mobile ticketing app (Mallat, Rossi, Tuuanainen & Öörni, 2009). Time of day is also related to a user's frequency of smartphone use (Andrews, Ellis, Shaw, Piwek, 2015). The term context however, is ambiguous and can refer to a diverse range of meanings. Venkatesh, Thong & Xu (2016) describe 4 variables which could be considered contextual constructs. The first 'Environmental attributes' denotes the lights, temperature and the immediate physical environment around a person when using technology. They also describe 'Location attributes' such as culture, regional economy and organisational competition. Events (time) can be considered a contextual variable as it signifies the temporal setting. Finally, 'Organization attributes' can also belong to this context theme, as it includes climate, organizational culture, leadership and collective technology use (Venkatesh, Thong & Xu, 2016).

Due to the scope of the current theory, *situational context* is defined as the immediate environment surrounding the person directly prior to using a technology. This definition is similar to 'Environmental Attributes', and includes the objects, people and current events that are part of the user's immediate surroundings. However, our adaption also incorporates the place and time as this can reflect a user's routine and habit, an important predictor of technology use (Stawarz, Cox & Blandford, 2015). Place reflects a user's GPS location which can provide details as to where the technology is being used (E.g. the country, city, or building) and other meaningful locations, such as whether the user is at home or work. Time reflects temporal attributes such as time of day and day of the week e.t.c. As a result, this new construct is termed *situational context*. It does not include social groups, organizations or societal attributes to which a user belongs due to the scope of the theory. Although, existing and future sociological theories such as the Diffusion of Innovation model may find these useful to describe when understanding how technology spreads (Rogers, 2003). Related concepts can be examined when measuring individual differences such as culture or occupation. By defining and reducing context to what is described above, we can ensure that *situational context* has practical value in subsequent research.

3.3.8. Technology Use

It is common across models to include a variable that represents the use of a technology (Davis, Bagozzi & Warshaw 1989; Venkatesh & Davis, 2000; Limayem, Cheung & Chan, 2003; Kim & Malhotra, 2005; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016). Very few designs have successfully measured objective usage (Turner et al., 2010; Andrews, Ellis, Shaw, Piwek, 2015). Instead, activity is predominately measured subjectively via self-reports methods as a substitute for actual logs of technology use (Shaikh & Karjaluoto, 2015; Taylor & Todd, 1995; Turner, et al. 2010). Conversely, behavioral intention is a variable often included in models (Davis, Bagozzi & Warshaw 1989; Bhattacherjee, 2001; Limayem, Cheung & Chan, 2003; Kim & Malhotra, 2005; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016) because it has been "posited by many theorists as the closest cognitive antecedent to actual behavior" (Setterstrom, Pearson & Orwig , 2013, p. 1141), and avoids issues with developing applications that can measure technology use such as programming barriers, consent form "blindness" and privacy/security issues (Piwek, Ellis & Andrews, 2016). However, in a review of 73 publications, the predictor variables in TAM were shown to be better at predicting behavioral intention than actual usage (Turner et al., 2010). Although challenging, attempts should be made to measure actual usage, through computer science collaborations or through the use of programming frameworks (Piwek, Ellis & Andrews, 2016; Andrews, Ellis, Shaw, Piwek, 2015). To encourage this direction and to promote parsimony, it is unnecessary to include in a model a substitute variable alongside a construct which represents actual technology use. Thus, the general theme of *Technology Use* is deemed more appropriate for future models as it concerns itself with actual use.

The first and most straightforward *technology use* measure that could be explored relates to a person's choice. Does a person choose to use a new system/technology or do they continue to use the systems and technology they already have? An additional measure involves collecting objective usage over time via the technology itself (Andrews, Ellis, Shaw, & Piwek, 2015). There is the assumption that increased use is indicative of greater levels of technological integration. However, it is proposed here that consistent patterns of use may be more symptomatic of successful technological integration than a sum of overall use. For example, do you use your phone alarm to wake you up every morning? Thus, is a technology used again when aiming to satisfy the same motivations, or used repeatedly in the same contexts? This highlights that continued technology use needs to be measured longitudinally to investigate how new habits and new patterns of *technology use* arise. It is also important to understand that there are often distinctive layers to any technology. Generalised mobile phone use for example, can be measured directly as a whole, or the use of a specific app can be quantified specifically. However, by defining exactly the technology to be measured, it is easier to develop applications and data logging platforms which can quantify the use of the technology under investigation. This will aid the unnecessary collection of data beyond the scope of the project, making analysis simpler, as data logging itself produces a large quantity of valuable data (Andrews, Ellis, Shaw, Piwek, 2015).

4. Discussion

4.1. Theoretical Contributions

TIM was developed to help predict technology use and impact, and to explain outstanding questions in the technology use literature. For example, multiple predictions can be generated regarding what contributes to long-term technology use. Based on the background that underpins TIM, we would predict that a technology will be used long-term if it repeatedly satisfies a user's intrinsic and extrinsic motivations and continually extends a person, as this causes the user to consider the technology worth using across time. In addition, we can also effectively consider why people use technology in the first instance. Technology often extends the acts and functions of a person when trying to satisfy a user's *intrinsic and extrinsic motivations*. Therefore, we have successfully created a framework which can increase our understanding of technology use.

Technology can have both positive and negative effects on the user and TIM extends the current knowledge base by proving a number of testable relationships that are likely to underpin this phenomenon. The inclusion of a new variable, *Technology Extension and Subtraction*, explains the positive and negative effects technology can have on the user. Why a person uses a technology despite potential negative effects is based on a person's *intrinsic and extrinsic motivations*, and the saliency of these motivations. The user goes through a *cost-benefit decision* making process, whereby if a technology helps satisfy a salient intrinsic motivation, such as an addiction, this might outweigh the costs associated with using the technology. Thus, the use of technology does not have to be rational. Therefore, TIM escapes the limitations of existing theories by considering the convoluted relationship between technology use and the impact it has on the end user. This was achieved by capturing the core human-technology relationship through advancing extended-self ideas (Belk, 1988).

Theories of technology use often state that habit is an important influence of use (Limayem, Cheung & Chan, 2003; Setterstrom, Pearson & Orwig, 2013; Kim & Crowston 2011; Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016). TIM also extends existing theoretical knowledge here by illustrating how habitual use may form. As the model iterates with every use, we can measure the proposition that *situational context* will become more predictive and the *cost/benefit decision* will become less predictive of technology use over time. The more a technology is used in response to situational cues, rather than conscious decision making, the more habitual a technology has become (Stawarz, Cox & Blandford, 2015).

4.2. Applied Impact

Understanding and predicting continued technology use requires interdisciplinary collaboration (Schulz et al. 2012). TIM encourages interdisciplinary research because designing effective features of technology requires expertise from engineering, creative arts, cognitive and computer scientists. Equally, understanding individual differences, motivations and decision making requires expertise from medicine, psychology and the social sciences more broadly. Measuring situational context may benefit from geographical science knowledge, and many other disciplines could provide novel ways to examine the relationships and variables in TIM. The interdisciplinary focus of TIM can prompt several new avenues of research and will hopefully allow the field to develop more quickly. Thus, TIM has the potential to be highly generative.

Through describing how the model iterates, TIM encourages longitudinal research through the long-term tracking of each variable, which is arguably fundamental in the study of continued technology use. A collaboration between social and computer scientists could promote the method of documenting objective logs of the technology being examined (Andrews, Ellis, Shaw, Piwek, 2015). Researchers could also further utilise methods derived from ecological momentary and ambulatory assessment to examine other variables such as context, individual differences and motivations. These methods study individuals in their natural setting, in real time by using smartphones and wearable technology to sample a person's current mood, heart-rate, location and other streams of data via several snapshots over time (Connor & Mehl, 2015). By looping the model iteratively, factors which lead to technological abandonment or long-term integration can be repeatedly measured using this methodology. For example, are the features of a technology the same, worse or improved? Is the technology still extending the person or has a person's motivation changed? Finally, is the user still residing in contexts that allows them to use the technology? All these points may predict why a technology stops being used. In practice, it is assumed that the same tools and measures of *Individual differences, Situational Context, Technological Features, Technology Extension and Subtraction, Intrinsic and Extrinsic Motivations, Agency, Cost/Benefit Decision* and *Technology Use* will be used repeatedly after a pre-defined length of time has passed since the last iteration. Therefore, TIM can be used to underpin longitudinal research.

The Technology Integration Model provides a tool for stakeholders to use with the purpose of aiding business practices, consumer satisfaction, technological design and other applications. TIM can be used by professionals in many occupations. Designers should seek to develop and refine technology which extends a person's mind, body, environment and possessions whilst minimising subtraction that will discourage use and have a negative impact on the user. Technology should be designed with the users' motivations in mind, whilst aiming to maximise the compatibility between technological features and the user. It may be possible for a consumer to pick a technology that is most suited to them. For example, when choosing a smartphone, it is possible that a person's individual differences will predict whether they should ideally purchase a smartphone with specific features (Shaw, et al. 2016). TIM moves the focus onto how technology can benefits consumers, and as a result technology developers and companies are assisted when creating technology that positively impacts the end user. A technology that is used long-term will offer greater value for money, and allow the consumer to master that particular technology, increasing feelings of agency. Future use may, in turn, indicate increased levels of satisfaction with a purchased technology (Bhattacherjee, 2001). As TIM explains technology integration beyond adoption and predicts future use, developers can use these predictions to produce satisfying and beneficial products for the user.

TIM describes how a technology might become a part of someone's everyday life, making it stand out from other theories created by researchers from an information systems or business management perspective (Venkatesh, Morris, Davis & Davis, 2003; Kim & Crowston, 2011; Davis, Bagozzi & Warshaw 1989; Bhattacherjee, 2001). However, its predictions can still be applied within occupational and educational settings. When implementing new systems in the workplace, consider employees perception of agency. If this is perceived to be low, companies can provide interventions such as training and practice sessions. In addition, management should ensure that a change in system will extend the employees possessions beyond the systems that are currently in place if they wish to encourage use. Whilst use of a new technology is largely mandatory in work environments, the integration process could be made more efficient and effective if the employees themselves view the technology as worth using even if it was optional. This may encourage more spontaneous use of the technology, as without the perception of a technology being worth using, it is likely that employees will use the technology to the minimum, rather than exploring a technology's full potential.

4.3. Limitations

While the model is derived from recent empirical work, and took inspiration from existing theories, future research is now required to empirically document or critique the relationships that we have defined. This will involve key decisions regarding how each aspect can be best measured. TAM is often relied on due to is its validated inventory of psychometric measurement scales (Yousafzai et al., 2007a). Moving forward, our model (TIM) will require its own standardised set of validated empirical methods and measures if it is to be effectively operationalised by other researchers.

Ultimately, the purpose of creating theories is to simplify the phenomena under investigation and allow for improved understanding. However, this requires a careful balance. Existing unification models have a multitude of constructs and a convoluted web of moderating and mediating variables that due to their lack of usability, rarely encourage further exploration of the phenomenon (Venkatesh, Thong & Xu, 2012; Venkatesh, Thong & Xu, 2016). On the other hand, traditional models like the TAM oversimplify the complex relationships between technology use and people. Such models lack the ability to generate new knowledge that can change subsequent engagement with technology (Davis, Bagozzi & Warshaw 1989). During the development of TIM, it was deemed important to continue refining the identified key themes (14 variables). TIM subsequently only developed constructs within a defined scope to limit the number of variables included in the final model. However, TIM takes inspiration from many disciplines to ensure thorough explanation of the chosen phenomenon, which focuses on an individual's technology use. Thus, one of the contributions of TIM is a balance of explanatory value and parsimony.

Like the TAM, it is unlikely that all the relationships and concepts in TIM will be tested simultaneously (Yousafzai, Foxall, & Pallister, 2007a). However, TIM can be broken into sections. For example, a researcher can measure what predicts *technology extension or subtraction*, the *cost-benefit decision* or *technology use*, as the variables which predict each of these constructs are shown in Figure 1. It can also be critiqued that variables such as *individual differences*, *intrinsic and extrinsic motivations* and *technological features* in TIM are broad in nature. However, it remains important that the described concepts in TIM are general enough for a wide range of technologies so that researchers do not need to test specific hypothesis for each study. It is possible to test idea that *individual differences* and *technological features* predict *technological extension or subtraction*, irrespective of which *individual difference* or *technological feature* under investigation. Equally, one can test the hypothesis that motivation influences the decision-making process by using a combination of different motivations. These features ensure that TIM will remain relevant as new technologies emerge.

4.4. Conclusions

TIM is a new model which predicts continued technology use and provides strong explanatory value whist maintaining parsimony and practicality. Each loop in TIM represents one use and this iteration is necessary as human-technology integration may not occur instantly, but develop over time. This can be measured by examining the individual contributions of conscious decision-making alongside automatic use in response to contextual cues across several iterations of the model. The model is generative, and can inspire a multitude of hypothesis driven research, largely due to the new relationships and concepts described. TIM promotes the development of technology that includes extending features, which satisfies a user's motivations, particularly if aimed to be used long-term. As a result, the model can be applied to a broad range of contexts, being able to adequately explain the use of existing and future technology. It encourages interdisciplinary collaborations and the exploration of new and objective research methods. In sum, TIM can accelerate progress and generate new knowledge in the ever growing and important field of continued *technology use.*

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