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Towards a Theory of “Use” in the Autonomous Things

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Abstract

The way users perceive and use information system artefacts has been mainly studied from the notion of behavioural believes, cognitive efforts, and deliberate use (e.g., clicking or scrolling) by human actors to produce certain outcomes. The autonomous things, however, do not require deliberate cognitive processes and physical actions to operate. Hence, the existing notions of *logical and deliberate use* by human actors to produce certain outcomes warrant a revisit. Consequently, drawing on the theories of consciousness and technology adoption, we proposed the notions of *conscious use* in the context of autonomous things. We argue that unlike the manually operated technologies and systems, the "use" of an autonomous artefact is a state of a user's consciousness rather than a logical, deliberate cognitive, or somatic activity. A fully autonomous artefact is consciously perceived by users anticipating their needs (through sensory information and situational awareness) without requiring any cognitive efforts, instructions, and physical contact to produce the desired outcomes.

Keywords autonomous things; conscious use; theory of consciousness.

1 Introduction

The way end users perceive and use information systems (IS) has been mainly studied on the premise of cognitive efforts (i.e., learning to use the system) and physical actions (of clicking, scrolling, pressing, or tapping) performed by the human actors (Adams et al. 1992; Delone and McLean 2003) to produce outcomes (Benbasat and Zmud 2003). However, the next generation of technologies does not involve any cognitive efforts, deliberate use, and instructions to operate (e.g., see (Ernst 2020a; Musk 2019; Sen et al. 2015). The next generation of technologies are autonomous (Inagaki and Sheridan 2019; Jayaraman et al. 2019), context-aware, adaptive, and interactive (Schuetz and Venkatesh 2020) having a distinct characteristic, unlike the conventional technologies that require physical contact and dependent on its users (Atzori et al. 2010).

Owing to these developments, the IS researchers have questioned the core assumptions of theorizing the use of IS artefacts (Lee et al. 2015) on the premise of cognitive and physical use thus calling for novel theoretical developments to deal with the "*entire domain of research questions that cannot yet be answered with our existing theories*" (Schuetz and Venkatesh 2020, p. 461). It is profoundly evident that the earlier theories were developed for a different genre of end-users faced with manually operated technologies (Benbasat and Zmud 2003; Rivard 2014). Hence, it is vital and timely to depart from the current practice (Hewitt et al. 2019; Zeitzew 2007) of theorizing the use associated with autonomous things on the premise of existing theories and advocate for novel theoretical underpinning (Rivard 2014; Schuetz and Venkatesh 2020). Aside from the theoretical value for academics, developing constructs for the emerging technologies will have greater practical benefits for the businesses who are keen to understand their customer needs and demand (Davis, 1989).

Consequently, this research aims to theorize and propose a core construct for the "use" associated with autonomous things. We draw on literature spanning from technology adoption (Davis 1989) to the theories of consciousness (Baars 1988; Rosenthal 1996) and propose a core construct for the autonomous things:

- **Conscious Use—** is an individualist state of a user's mind when an autonomous artifact is carrying out tasks and activities for which the system is designed to support it.

We argue that unlike the manually operated IS artefacts (Lee et al. 2015), the "use" of an autonomous artefact is an individualistic state of consciousness rather than a cognitive and somatic activity. Simply put, when a fully autonomous IS artefact does not require cognitive efforts, physical contact, and instruction to operate, its "use" becomes an individualist state of a user's mind rather than a deliberate activity of pushing a button or clicking on a screen to produce certain outcomes. Users consciously perceive a fully autonomous artefact anticipating their needs (through sensory information and situational awareness) without requiring any instructions and physical intervention.

The rest of the article is as follows. Next, we briefly discuss the current notion of the "use" and draw conceptual boundaries around our theorization by constructing and elaborating a continuum developed through extensive literature reviews. This is followed by discussing the theories that we leveraged to develop the constructs for autonomous things. We conclude with a discussion summarizing the contribution of the study and the future research avenues available to extend this research.

2 The Existing Notions of "Use"

Over the last several decades, a significant amount of research has been dedicated to theorizing and examining the way individual (Venkatesh et al. 2003), groups (Brown et al. 2010), and organizations (Del Aguila-Obra Ana and Padilla-Meléndez 2006) perceive and use certain technologies and IS. Although countless IS theories are available (for example see (Levy and Ellis 2006) for a list of IS theories), predominantly the technology adoption theory advanced by Davis (1989) and later extended, shaped, and reshaped by several researchers (Adams et al. 1992; Delone and McLean 2003; Marangunić and Granić 2015; Seddon 1997; Venkatesh et al. 2003) has profoundly expanded our understanding of the way people accept or reject certain technologies and systems. Among the core notions that explain a user's accepting or rejecting technology is the "perceived ease of use" which is defined as the "*degree to which a person believes that using a particular system would be free of efforts*." (Davis, 1989) (p. 320). Moreover, if the technology is perceived to be "easy to use" then it is more likely to tangibly "use" it (Adams et al. 1992) which is defined as "*the extent that a user utilizes the IS to carry out tasks and activities on the job for which the information system is designed to* *support*” (Sun and Teng 2012, p. 1565). These notions of technology use rest on several assumptions (Schuetz and Venkatesh 2020) and postulate the “use” associated with an IS artefact on the premise of cognitive efforts (i.e., learning to compose an email), physical actions (of clicking, scrolling, pressing, or tapping) performed by users (Adams et al. 1992; Delone and McLean 2003) to produce certain outcomes (such as sending an email) (Benbasat and Zmud 2003). Almost every hypothesis dealing with information systems and technology perceptions, attitudes, behaviors, and intentions (Lee et al. 2003; Taylor and Todd 1995; Venkatesh et al. 2003), values, satisfaction, and system characteristics, success, and failure (Delone and McLean 2003) lead to use (Figure 1). And few roads even go beyond the use and look into IS post-use behaviour and consequences (Ahuja and Thatcher 2005). IS use has also been extensively investigated in a variety of levels, such as individuals and group level, and contexts, such as business context, domestic context, education context, healthcare, military, and cultural contexts (Figure 1).

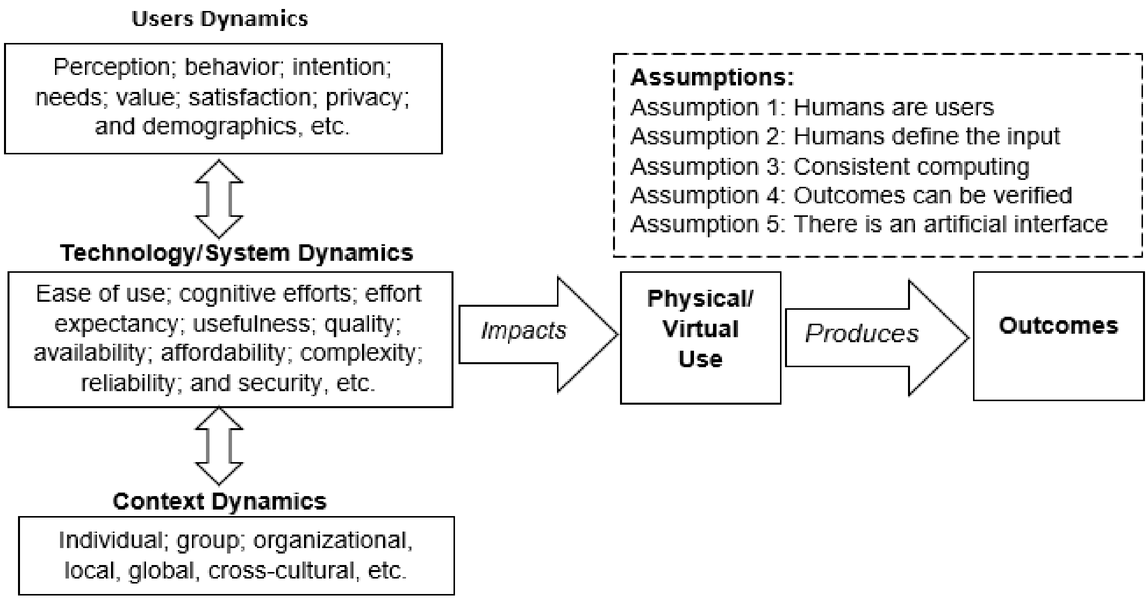

Figure 1: Existing notions of information systems/technology use

In agreement with these assumptions, the use of an IS artefact has been theorized as “intentional and deliberate” (Schuetz and Venkatesh 2020) dealing with the users’ perception of cognitive efforts and somatic use associated with IS artefacts. While this theorization is flawless, it runs into infinite regress when dealing with the autonomous things that do not require any cognitive efforts and human intervention or *somatic use* to produce desired outcomes (Schuetz and Venkatesh 2020). The way end-users interact with IS artefacts (Lee et al. 2015) has come a long way from humble beginnings of interacting with punch cards to keyboards and mouse, touch screens, and now to interactions with autonomous things not requiring any inputs (Ernst 2020b; Musk 2019; Ronkainen et al. 2007; Sen et al. 2015). Owing to these technological developments, a new genre of IS research is emerging which questions the traditional notions of theorizing the users’ beliefs and interactions with autonomous systems on the premise of cognitive efforts and physical use (Demetis and Lee 2018). Schuetz and Venkatesh (2020) argue that human-like artificially intelligent systems break down the prevalent unilateral notions of “user-artefact interaction” where a human is assumed as a deliberate user of the system. The role of the human as active users is also challenged by Demetis and Lee (2018) by advancing the notion of “role-reversal” between human and technology where humans are considered as artefacts shaped and used by technology and not the other way around. Hence, we propose an alternative notion “use” in the context of autonomous things, discussed next.

3 Conceptual Boundaries

To draw a conceptual boundary around our theorization, a continuum was developed based on the key aspects of autonomous technologies discussed in the literature (Figure 2) (burst detection technique was employed to investigate the emerging research themes; see the appendix). Table 1 explains these aspects. The “use” related assumptions listed in Table 1 are derived based on theoretical reasoning provided in the subsequent sections and the conceptualization provided by Schuetz and Venkatesh

(2020). One of the core facets that distinguish the next generations of technologies from conventional technologies is the state of its autonomy (Ernst 2020a). Autonomy has several levels from being completely autonomous, partially autonomous, to non-autonomous things (Inagaki and Sheridan 2019). Following the autonomy standards reported in the literature (Endsley 1999; Inagaki and Sheridan 2019) and by considering the key attributed of the autonomous IS artefact proposed by Schuetz and Venkatesh (2020), we created a generic taxonomy of the autonomous things as shown in the continuum (Figure 2). For this research, we define an autonomous IS artefact (AIA) as any physical (or virtual) IS artefact that can work independently without any human intervention (e.g., self-driving cars, drones, virtual agents, and robots). AIA take in sensory data, interpret the information, and respond accordingly. The main differentiator among the level of autonomy, in our approach, is the need for 1) cognitive efforts, 2) physical contact, and 3) instructions to operate an autonomous IS artefact. At the one end of the continuum (Figure 2) are fully autonomous IS artefacts that do not require any cogntivie efforts, physical contact, and instructions to function; whereas, at the other end are the 'manual technologies' that always require cognitive efforts, instructions, and physical use. These are explained below. It is noted that the continuum itself does not capture all possible types of systems having a more blended set of interactions, for simplicity sake we capture and explain the three distinct types.

3.1 Fully Autonomous IS Artefact (FAISA)

FAISA is any (physical or virtual) IS artefact (Lee et al. 2015) that does not require cognitive efforts, physical contact, and instructions to produce outcomes in all situations permanently. Such an IS artefact is constantly learning and anticipating users' needs using sensory data without requiring human intervention. The FAISA is autonomous, context ware (Irene and Susan 2017), adaptive, interactive, and stateful (Schuetz and Venkatesh 2020). With major advancements in the fields of engineering, robotics, and artificial intelligence, coupled with improved computational power and network availability, autonomous things are now becoming ubiquitous across many industries. Examples of FAISA include autonomous vehicles (Bimbraw 2015; Jayaraman et al. 2019) and robots (Kwak et al. 2017; Pellenz et al. 2009), autonomous virtual agents (Kramer et al. 2014; (Wang et al. 2018), smart mirrors (Hossain et al. 2007), to name a few. Furthermore, a FAISA can either be visible to naked, invisible (blended in the background or implanted in the body), virtual (such as a software product), or physical (such as a vacuum cleaner).

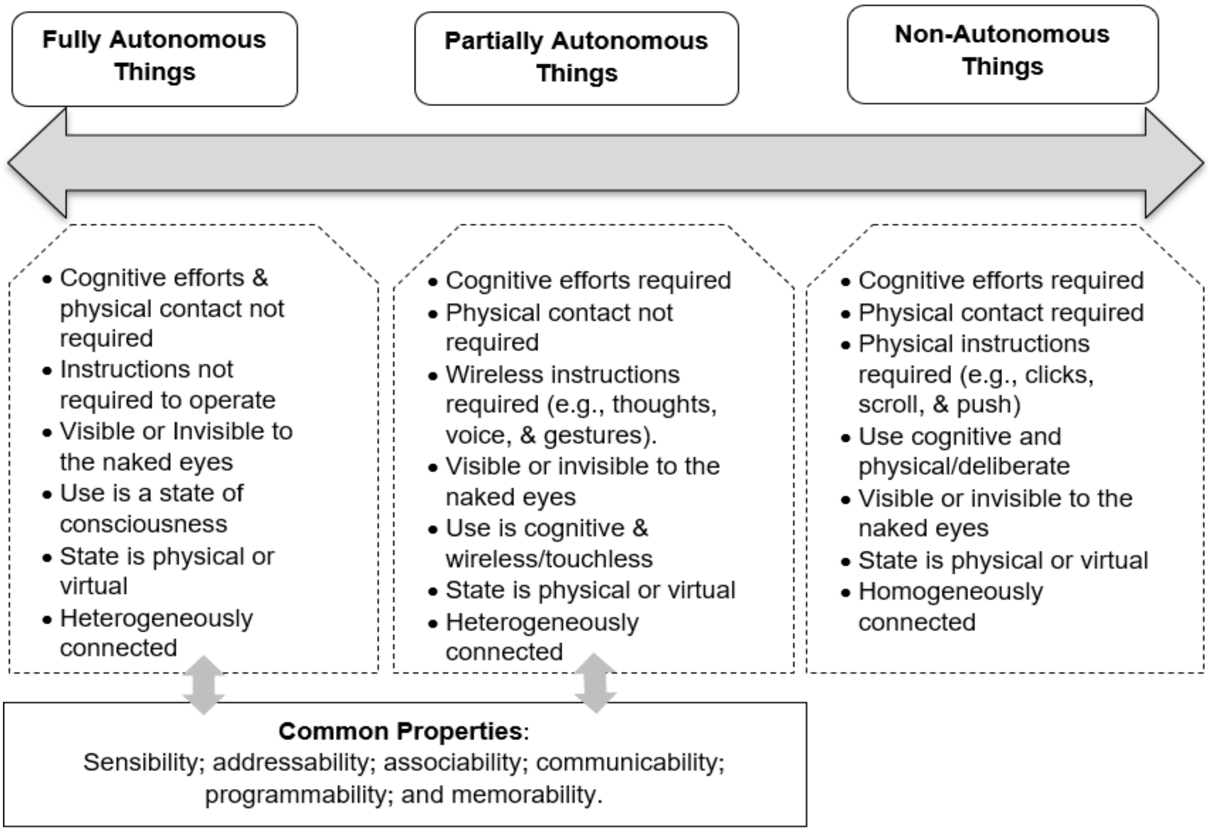

Figure 2. Autonomous Things Continuum

Facets	Full Autonomy	Partial Autonomy	No Autonomy	Description
Cognitive efforts and physical contact	Cognitive efforts and physical contact is not needed.	Cognitive efforts required but physical contact is not needed.	Cognitive efforts & physical contact is needed.	Cognitive efforts & physical contact is not required to operate fully and partially autonomous IS artefacts but it is a core element of the non-autonomous things.
Instructions	Instructions to operate are not needed.	The instructions to operate are cognitive, vocal, or gestural.	The instructions are physical.	While a fully autonomous IS artefact works without any instructions, a partially autonomous artefact operates on the principle of wireless instructions (in form of thoughts, voice, & gestures); whereas, the non-autonomous artefacts need physical instructions to operate (e.g., clicks, scroll, & push).
Use	The use is a state of consciousness.	The use is cognitive, vocal, or gestural.	The use is physical and somatic.	Given that a fully autonomous artefact does not require physical contact or instruction to operate, its use becomes a state of consciousness rather than a physical activity (i.e., pushing a button or clicking on a screen); whereas, the use of a partially autonomous thing is cognitive, vocal, or gestural not requiring physical intervention. However, the non-autonomous things require physical (active) use in the form of clicks, scroll, & push.
Visibility	Visible or invisible to the naked eye.	Visible or invisible to the naked eye.	Visible or invisible to the naked eye.	Visibility is a non-differentiator but it if is combined with autonomy it becomes a key aspect of the fully autonomous artefacts.
State	The state is either physical or virtual	The state is either physical or virtual	The state is either physical or virtual	All these IS artefacts can be either physical (atoms) or virtual (bits) in nature.
Connectivity	Heterogeneously connected.	Heterogeneously connected.	Homogeneously connected.	The fully (and partially) autonomous things connect heterogeneously to dissimilar things (e.g., the connection among the home appliance aka. IoT); whereas, the non-autonomous things homogeneously connected to similar technologies (e.g., a smart-to-smart phone and personal-to-personal computer connections).

Table 1. Key Characteristics of the Next Generation of Things

3.2 Partially Autonomous IS Artefact (PAISA)

PAISA is any (physical or virtual) IS artefact that does not require physical contact but needs cognitive efforts and instructions to produce outcomes in all situations permanently. The instructions needed can be cognitive, gestural, or speech-based wirelessly communicated through a variety of mechanisms (discussed in later sections). In this scenario, physical contact (e.g., push or click) is not required but the system still needs instructions to operate.

Examples of PAISA include voice commanded systems (e.g., Siri and Alexa) (Sen et al. 2015); systems that are controlled with thoughts (e.g., Elon Musk's Neuralink) (Musk 2019), and gestures enabled systems (e.g., SelfieType, a gesture-based virtual keyword developed by Samsung).

3.3 Non-Autonomous IS Artefact (NAISA)

NAISA is any (physical or virtual) IS artefact that requires cognitive efforts, physical contact, and instructions to produce outcomes in all situations permanently. The instructions are provided in the form of physical actions performed by the users (e.g., clicking on a screen). Most conventional technologies come under this category (e.g., a smartphone, personal computers, and email agents, word-processing, so forth). These technologies may have a certain level of automation but based on our criteria of requiring physical contact and instructions to operate, they are classified as non-autonomous from the users' perspective.

4 "Use" in Fully Autonomous Artefacts

As alluded earlier, the two core notions of a FAISA are that it does not require (1) *cognitive efforts* (2) *physical contact*, and (3) *instructions* from human actors to produce certain outcomes. Consider, for instance, Kai a fully autonomous hazard detection robot (working in a supermarket in New Zealand and Australia) capable of operating on its own using sensory information and situational awareness. Given that Kai does not require cognitive efforts, physical contact, and instruction to operate, the conventional understanding of use associated with a technology warrants a different understanding. When there are no cognitive efforts and physical (or virtual) use involved, *how then a user uses a FAISA such as Kai or any other autonomous IS artefact*? Schuetz and Venkatesh (2020) argue that when dealing with cognitive computing systems, humans shouldn't be assumed as a deliberate user of the system rather artefacts use users to achieve their objectives. Similarly, Demetis and Lee (2018) notion of "role-reversal" posit humans as artefacts shaped and used by technology and not the other way around.

We, however, argue that although the use of a FAISA is not deliberate and cognitive, the user is *conscious* of its presence. Such a use can be characterized as "low attention" and/or "low intension" automatic use not requiring thoughtful human inputs (Dix 2017). For example, the light in a room may switch-off as you the occupant goes into a sleep state. Context-awareness plays a crucial role in characterizing the situation of users as it takes into account all information relevant to the interaction between a user and an application, including the user and applications themselves (Dey 2001). Furthermore, even if the autonomous system is operating smoothly, the user is generally aware of the system and will expect the tasks (automatically performed by the system) that are entirely below the user's awareness (Dix 2017). In other words, the user consciously perceives an autonomous IS artefact in service anticipating their needs without requiring any cognitive efforts and physical or virtual intervention. In this sense, the *use* of FAISA becomes a subject of human consciousness rather than a matter of cognition and physical use associated with operating manual technology to produce certain outcomes. Hence, contrary to the current practice of theorizing the use associated with FAISA on the premise of technology adoption theory (Hewitt et al. 2019; Zeitzew 2007), we advocate for leveraging the theories on human consciousness.

Human consciousness has been a complex and puzzling construct of physiological sciences for centuries (Baars 1988). More recently, significant interdisciplinary research has been dedicated to understanding consciousness—both biologically and psychologically—in cognitive science, involving fields such as psychology, linguistics, anthropology, and neuroscience, to name a few. The theory of consciousness explains consciousness as a state of being aware of an external object or something within oneself (Baars 1988; Rosenthal 1996) and the Oxford Living Dictionary defines consciousness as "the state of being aware of and responsive to one's surroundings." A more recent theory (Marchetti 2018) (p. 435) suggests that "consciousness is a special way of processing information" due to three vital cognitive procedures namely, the self, attention, and working memory.

The self, which is articulated mainly by the central and peripheral nervous systems, helps individuals' map their bodies, the world, and our relationships with the world. Attention "allows for the selection of those variations in the state of the self that are most relevant in the given situation," and finally a working memory is needed to assemble the selected specific pieces of information through attention (Marchetti 2018) (p.435). This unique way of processing information produces (rather transmitting) individualized information meaningful for the person who consciously experiences it, and it has "that" meaning only for the person experiencing it, not for other people (Marchetti 2018). In the context of autonomous things, for example, I know what it means for me to experience an autonomous thing but another person cannot directly know what it means for me to experience the IS artefact (and vice versa). In other words, experiencing and using a FAISA is a very individualist state of consciousness producing meaningful information about the FAISA not accessible to others. This individualist conscious state of mind allows users to process information based on their desires while consciously being aware of a FAISA at their disposal. The users consciously perceive a FAISA in service anticipating their needs through sensory information and situational awareness without requiring any instructions and physical contact. Furthermore, our conscious inform us in real-time about the impact an external object (in this case a FAISA) will have on us, where the object is relative to us now, whether we can cope with it (Marchetti 2018).

Hence, we propose the notion of *conscious use which is* an individualist state of consciousness when an autonomous artefact is carrying out tasks and activities for which the system is designed to support. The construct theorizes the "use" associated with an autonomous artefact as states of consciousness rather than cognitive and physical or somatic activities. Unlike the "use" associated with the manually operated technologies that require cognitive efforts and physical actions (such as pushing a button or clicking on a screen), a fully autonomous artefact is consciously perceived by the users anticipating their needs through sensory information and situational awareness without requiring any cognition, instructions, and physical contact. Hence, the use associated with a fully autonomous IS artefact are individualistic states of consciousness anticipating a fully autonomous IS artefact at one's disposal.

5 Concluding Remarks

In this research, we advanced an alternative understanding of the *use* in autonomous things and proposed a novel construct: *conscious use*. We argue that unlike the physically operated IS artefacts, the "use" of a fully autonomous artefact is an individualistic state of consciousness rather than a cognitive or physical activity. In simple words, the *use* associated with an IS artefact that does not require cognition, physical contact, and instruction (to produce outcomes) is essentially a state of consciousness rather than a deliberate activity of pushing a button or clicking on a screen. A fully autonomous artefact sense, reason, and response to a user's needs without requiring any instructions and physical intervention. This understanding is advanced based on theories of consciousness (Baars 1988; Rosenthal 1996) combined with the way fully autonomous artefacts function i.e., by anticipating user's needs through sensory information and situational awareness without requiring any instructions and physical contact. These proposed theorization and construct are in agreement with the emerging strain of research that questions the core assumptions of theorizing the use of IS artefacts on the premise of cognitive and physical use (Demetis and Lee 2018; Rivard 2014; Schuetz and Venkatesh 2020). We have shown that the use associated with autonomous things "*cannot yet be answered with our existing theories*" (Schuetz and Venkatesh 2020, p. 461) as they were developed for a different genre of end-users technologies (Benbasat and Zmud 2003; Rivard 2014). In line with the IS custom of advancing new understanding for the emerging technologies (Davis et al. 1989), we believe that the construct proposed in this research will have greater theoretical value for academics and practical benefits for the businesses who are keen to understand end-user perceptions and needs related to autonomous things. Validating and extending the proposed construct will profoundly expand our understanding of the way people accept or reject autonomous things that do not require any physical contact or instructions to produce outcomes.

Future research is needed to expand our understanding of the relationship between the proposed constructs and how they are associated with other variables such as ease of use and usefulness (Adams et al. 1992). Given that there is no actual use involved, the relations of FAISA to the use is a rather interesting one. The user consciously perceives FAISA in service anticipating their needs without actually using the technology. Furthermore, it is well established that our consciousness plays a greater role in having perceptions and feelings (Marchetti 2018). Future research is needed to understand how the conscious experiences arising from having a FAISA in service lead to the forming beliefs and perceptions related to the artefact. The research has several limitations that need to be addressed. We did not propose any measures for the construct and the psychometric properties of the proposed constructs were not empirically validated, hence questioning its content (Nunnally 1978) and face validity (Broder et al. 2007). This limitation, however, also opens a new venue for the IS researchers to propose new measures for the construct and valid the psychometric properties of the proposed constructs and measure. Besides, we only looked into the use associated with a FAISA assuming that the users are aware of its presence. However, there may arise scenarios when a user is not conscious or aware of a FAISA which is anticipating their needs (such as chatbots, recommender systems, or products embedded in the environment) (Schuetz and Venkatesh 2020). Such scenarios render the need to measure the use of an invisible FAISA absolute.

Finally, looking at the continuum, several plausible scenarios may arise in addition to the ones laid down here. Such as a FAISA may exhibit state transition property switching from a fully autonomous state to a partial or non-autonomous state. For example, a self-driving vehicle can transit from a fully autonomous state to a manually controlled state when the need arises (Politis et al. 2018). A variety of strategies and design elements are suggested to facilitate this transition including rich displays (Eriksson et al. 2017) and a dialogue interaction system (Politis et al. 2018). However, for the sake of simplicity, in this article, we only investigated fully autonomous things. Although, we believe that construct theorized proposed here can readily be employed to theorize the transitional states of IS artefacts and the IS artefacts fitting into more than one scenario on the continuum (such as a voice-enabled IS artefact requiring a touch to activate it); however, more research is needed to understand use associated with the scenarios or product configuration not covered in this research.

6 References

Adams, D. A., Nelson, R. R., and Todd, P. A. 1992. "Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication," *MIS Quarterly* (16:2), pp. 227–247.

Ahuja, M., and Thatcher, K. J. B. 2005. "Moving Beyond Intentions and toward the Theory of Trying: Effects of Work Environment and Gender on Post-Adoption Information Technology Use," *MIS Quaterly* (29:3), pp. 427–459.

Atzori, L., Iera, A., and Morabito, G. 2010. "The Internet of Things: A Survey," *Computer Networks* (54:15), pp. 2787-2805.

Baars, B. 1988. *A Cognitive Theory of Consciousness*. Cambridge, UK: Cambridge University Press.

Benbasat, I., and Zmud, R. 2003. "The Identity Crisis within the Is Discipline: Defining and Communicating the Discipline's Core Properties," *MIS Quarterly* (27:2), pp. 183-194.

Bimbraw, K. 2015. "Autonomous Cars: Past, Present and Future - a Review of the Developments in the Last Century, the Present Scenario and the Expected Future of Autonomous Vehicle Technology," *In , Proceedings of ICINCO 2015 - 12th International Conference on Informatics in Control, Automation and Robotics* (1), pp. 191-198.

Broder, H. L., McGrath, C., and Cisneros, G. J. 2007. "Questionnaire Development: Face Validity and Item Impact Testing of the Child Oral Health Impact Profile," *Community dentistry and oral epidemiology* (35), pp. 8-19.

Brown, S. A., Dennis, A. R., and Venkatesh, V. 2010. "Predicting Collaboration Technology Use: Integrating Technology Adoption and Collaboration Research," *Journal of Management Information Systems* (27:2), pp. 9-54.

Del Aguila-Obra Ana, R., and Padilla-Meléndez, A. 2006. "Organizational Factors Affecting Internet Technology Adoption," *Internet Research* (16:1), pp. 94-110.

Delone, W., and McLean, E. 2003. "The Delone and Mclean Model of Information Systems Success: A Ten-Year Update," *Management Information Systems* (19), pp. 9-30.

Demetis, D., and Lee, A. S. 2018. "When Humans Using the It Artifact Becomes It Using the Human Artifact," *Journal of the Association for Information Systems* (19:10), pp. 929-952.

Dey, A. K. 2001. "Understanding and Using Context," *Personal and Ubiquitous Computing* (5:1), pp. 4-7.

Dix, A. 2017. "Activity Modelling for Low-Intention Interaction," in *The Handbook of Formal Methods in Human-Computer Interaction,* B. Weyers, J. Bowen, A. Dix and P. Palanque (eds.). Cham: Springer International Publishing, pp. 183-210.

Endsley, M. R. 1999. "Level of Automation Effects on Performance, Situation Awareness and Workload in a Dynamic Control Task," *Ergonomics* (42:3), pp. 462-492.

Eriksson, A., Petermeijer, S. M., Zimmermann, M., De Winter, J. C., Bengler, K. J., and Stanton, N. A. 2017. "Rolling out the Red (and Green) Carpet: Supporting Driver Decision Making in Automation-to-Manual Transitions," *IEEE Transactions on Human-Machine Systems* (49:1), pp. 20-31.

Ernst, C. 2020a. *Artificial Intelligence and Autonomy: Self-Determination in the Age of Automated Systems*. Cham: Springer International Publishing.

Ernst, C. 2020b. "Artificial Intelligence and Autonomy: Self-Determination in the Age of Automated Systems," in *Regulating Artificial Intelligence,* T.W.a.T. Rademacher (ed.). Cham: Springer International Publishing, pp. 53-73.

Hewitt, C., Politis, I., Amanatidis, T., and Sarkar, A. 2019. "Assessing Public Perception of Self-Driving Cars: The Autonomous Vehicle Acceptance Model," *Proceedings of the 24th International Conference on Intelligent User Interfaces* (Marina del Ray, California), pp. 518-527.

Inagaki, T., and Sheridan, T. B. 2019. "A Critique of the Sae Conditional Driving Automation Definition, and Analyses of Options for Improvement," *Cognition, Technology & Work* (21:4), pp. 569-578.

Irene, C. L. N., and Susan, Y. L. W. 2017. "The Internet-of-Things: Review and Research Directions," *International Journal of Research in Marketing* (34:1), pp. 3-21.

Jayaraman, S. K., Creech, C., Tilbury, D. M., Yang, X. J., Pradhan, A. K., Tsui, K. M., and Robert, L. P. 2019. "Pedestrian Trust in Automated Vehicles: Role of Traffic Signal and Av Driving Behavior," *Frontiers in Robotics and AI* (6:117).

Khan, G. F., and Trier, M. 2019. "Assessing the Long-Term Fragmentation of Information Systems Research with a Longitudinal Multi-Network Analysis," *European Journal of Information Systems* (28:4), pp. 370-393.

Kleinberg, J. 2003. "Bursty and Hierarchical Structure in Streams," *Data Mining and Knowledge Discovery* (7:4), pp. 373-397.

Kwak, S. S., Kim, J. S., and Choi, J. J. 2017. "The Effects of Organism- Versus Object-Based Robot Design Approaches on the Consumer Acceptance of Domestic Robots," *International Journal of Social Robotics* (9:3), pp. 359-377.

Lee, A. S., Thomas, M., and Baskerville, R. L. 2015. "Going Back to Basics in Design Science: From the Information Technology Artifact to the Information Systems Artifact," *Information Systems Journal* (25:1), pp. 5-21.

Lee, Y., Kozar, K. A., and Larsen, K. R. T. 2003. "The Technology Acceptance Model; Past, Present and Future," *Communication of AIS* (12:50), pp. 752-780.

Levy, Y., and Ellis, T. 2006. "A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research," *International Journal of an Emerging Transdiscipline* (9).

Marangunić, N., and Granić, A. 2015. "Technology Acceptance Model: A Literature Review from 1986 to 2013," *Universal Access in the Information Society* (14:1), pp. 81–95.

Musk, E. 2019. "An Integrated Brain-Machine Interface Platform with Thousands of Channels," *bioRxiv*), pp. 703-801.

Nunnally, J. C. 1978. *Psychometric Theory (2nd Ed.)*. New York, NY: McGraw-Hill.

Pellenz, J., Gossow, D., and Paulus, D. 2009. "Robbie: A Fully Autonomous Robot for Robocuprescue," *Advanced Robotics* (23), pp. 1159-1177.

Politis, I., Langdon, P., Adebayo, D., Bradley, M., Clarkson, P. J., Skrypchuk, L., Mouzakitis, A., Eriksson, A., Brown, J. W., and Revell, K. 2018. "An Evaluation of Inclusive Dialogue-Based Interfaces for the Takeover of Control in Autonomous Cars," *In Proceedings of 23rd International Conference on Intelligent User Interfaces*, pp. 601-606.

Rivard, S. 2014. "The Ions of Theory Construction," *MIS Quarterly* (38:2), pp. iii-xiii.

Ronkainen, S., Häkkilä, J., Kaleva, S., Colley, A., and Linjama, J. 2007. "Tap Input as an Embedded Interaction Method for Mobile Devices," *In Proceedings of TEI 2007*), pp. 263-270.

Rosenthal, D. M. 1996. "A Theory of Consciousness," in *The Nature of Consciousness,* O.F. N. Block, and G. G¨uzeldere (ed.). Cambridge, MA: MIT Press.

Schuetz, S., and Venkatesh, V. 2020. "Research Perspectives: The Rise of Human Machines: How Cognitive Computing Systems Challenge Assumptions of User-System Interaction," *Journal of the Association for Information Systems* (21:2).

Sci2Team. 2009. "Science of Science (Sci2) Tool (Indiana University and Scitech Strategies, 2009)." http://sci2.cns.iu.edu.

Seddon, P. B. 1997. "A Respecification and Extension of the Delone and Mclean Model of Is Success," *Information Systems Research* (8:3), pp. 240-253.

Sen, S., Chakrabarty, S., Toshniwal, R., and Bhaumik, A. 2015. "Design of an Intelligent Voice Controlled Home Automation System," *International Journal of Computer Applications* (121), pp. 39-42.

Sun, J., and Teng, J. T. C. 2012. "Information Systems Use: Construct Conceptualization and Scale Development," *Computers in Human Behavior* (28:5), pp. 1564-1574.

Taylor, S., and Todd, P. A. 1995. "Understanding Information Technology Usage: A Test of Competing Models," *Information Systems Research* (6), pp. 144-176.

Venkatesh, V., Morris, M., Davis, G., and Davis, F. 2003. "User Acceptance of Information Technology: Toward a Unified View," *MIS Quarterly* (27), pp. 425-478.

Wang, W., Xu, J., and Wang, M. 2018. "Effects of Recommendation Neutrality and Sponsorship Disclosure on Trust Vs. Distrust in Online Recommendation Agents," *Moderating Role of Explanations for Organic Recommendations* (64:11), pp. 5198-5219.

Zeitzew, M. 2007. "Autonomous Utility Mower," in: *Agricultural Engineering International: CIGR EJournal*.

7 Appendix A

Burst Detection

In this study, we employed Kleinberg's burst detection algorithm (Kleinberg 2003) implemented in the Sci2 tool (Sci2Team 2009) to identify the emerging trends in the autonomous things research domain. The burst detection technique is a reliable way to identify emerging trends in any research domain by analysing large corpora of text (Kleinberg 2003). Researchers from a variety of domains including the information systems domain (Khan and Trier 2019) have successfully employed this technique to identity emerging trends in their respective research domains. Before applying the burst detection techniques, the data were lowercased, tokenized, and a common set of stop words were removed from it.

Data

The data for burst detection were obtained from the Web of Science (WoS) database. Previous research has shown that the keywords and titles of the articles are the best places to identify the emerging trends in a domain (Leydesdorff, 2006). Hence, we entered a research query into the WoS search engine to find the publications (from 2000 to early 2020) with the following topics in the keywords, title, and abstract of the articles.

> ***Searched for topic**: ("autonomous things" OR "autonomous systems" OR "autonomous products" OR "autonomous artifact " OR "autonomous robots" OR "autonomous machines" OR "self-governing things" OR "self-governing systems" OR "self-governing artifacts" OR "self-governing product" OR "self-governing robots" OR "self-governing machines" Timespan*: 2000-2020. Indexes: Social Sciences Citation Index (SSCI).

The search retrieved 252 articles that had appeared in 156 journals. Furthermore, a vast majority of articles (70%) were published since 2011 and the largest number of publications (n=20) appeared in Adaptive Behavior Journal. This was followed by 9 (3.6%) articles in Ethics and Information Technology, 8 (3.2%) in Ergonomics and Human Factors each. None has appeared in the top IS journals, which is consistent with the conclusion reached by (Schuetz and Venkatesh, 2020), 6 (2.4%) in Bulletin of the Atomic Scientists, and 5 (2%) in Cognitive Systems Research.

Results

Table A and B shows the bursting topics included in the titles of the articles and the keywords supplied by authors with their weight, length, start year, and end year. In the case when there is no end date noted, the terms are considered to still active. The burst words with the start year indicate that the word started appearing in that year and the end year indicates the year that the word last appeared. The burst words without an end year are for those intervals which extend to the most recent publications, suggesting terms that are in the middle of a large weight burst at present (Kleinberg 2003). The length represents the period of the burst word measured in the number of years.

Currently, the most significant fading research trends represented in the field of autonomous things from a title perspective (Table A) include neural (2001-2008), improve (2015-2011), control (2001-2007), determin (2010-2015), individu (2004-2009), and spatial (2008-2012). And the themes that are still active include embed (2016-present), ethic (2018-present), mental (2017-present), machin (2018-present), autom (2018-present), and accept (2018-present). These highlight potential areas of research that are very much the focus of contemporary. On the other hand, the author-supplied keyword analysis (Table B) also shows which areas of research are not active as they once were; these include the likes of dynam (2002–2015), function (2002–2012), activ (2000–2010), and mobil (2000-2009). Furthermore, the research topics that are still actively pursued are team (2017-present), analysi (2018-present), driverless (2018-present), car (2018-present) and driver (2019-present), so forth. This shows that most of the research on autonomous things seems to be focused on driverless cars and the issue associated with it. The appearance and disappearance of words also indicate that the research area and priorities are changing over the years.

Table A: Top Bursting & Disappearing Topics (Stem Words) in Titles of the Articles

Word	Weight	Length	Start	End	Word	Weight	Length	Start	End
neural	1.45	8	2001	2008	network	1.62	3	2000	2002
improv	1.46	7	2005	2011	AI	0.87	2	2016	2017
situat	1.10	7	2004	2010	convers	0.78	2	2009	2010
control	1.87	7	2001	2007	embodi	1.19	2	2012	2013
determin	1.16	6	2010	2015	humanoid	1.12	2	2013	2014
individu	0.82	6	2004	2009	design	1.44	2	2019	
spatial	0.95	5	2008	2012	user	1.24	2	2019	
embed	1.11	5	2016		intellig	1.27	2	2017	2018
unman	0.90	5	2010	2014	trust	1.30	2	2019	
play	0.90	5	2010	2014	drive	1.53	2	2019	
mental	1.06	4	2017		human	4.00	2	2019	
ethic	1.84	3	2018		context	0.93	2	2019	
machin	2.47	3	2018		experi	0.81	2	2019	
autom	2.28	3	2018		interact	1.08	2	2019	
voic	0.82	3	2007	2009	interfac	1.82	2	2019	
speech	1.53	3	2009	2011	adapt	1.13	2	2001	2002
develop	0.98	3	2012	2014	robot	0.97	2	2001	2002
context	0.80	3	2010	2012	dialogu	1.79	2	2010	2011
intellig	1.62	3	2001	2003	interfac	0.84	2	2010	2011
smart	1.60	3	2016	2018	cognit	1.14	1	2018	2018
accept	0.91	3	2018		decis	0.95	1	2012	2012
global	0.91	3	2018		autonom	1.04	1	2003	2003
defin	0.91	3	2018		learn	1.23	1	2001	2001

Table B: Top Busting & Disappearing Topics in the Author-Supplied Keywords

Word	Weight	Length	Start	End	Word	Weight	Length	Start	End
dynam	2.57	13	2002	2014	agent	2.41	3	2011	2013
function	1.85	11	2002	2012	driverless	1.56	3	2018	
activ	1.74	11	2000	2010	theori	1.78	3	2011	2013
mobil	2.03	10	2000	2009	netswork	1.55	3	2000	2002
eye	1.55	9	2005	2013	car	2.99	3	2018	
visual	1.83	7	2010	2016	moral	1.69	2	2015	2016
evolutionari	1.74	7	2002	2008	driver	1.64	2	2019	
emerg	1.96	7	2008	2014	respons	2.16	2	2014	2015
imit	1.7	5	2004	2008	attent	1.62	2	2009	2010
unman	1.56	5	2010	2014	engin	1.89	2	2017	2018
organ	1.8	5	2004	2008	vehicl	2.2	2	2019	
afford	1.57	5	2007	2011	intellig	1.74	2	2000	2001
self	1.62	5	2004	2008	robot	1.94	2	2006	2007
behavior	1.83	4	2008	2011	drive	1.76	2	2019	
learn	2.06	4	2005	2008	social	1.65	2	2003	2004
team	1.74	4	2017		agent	1.85	2	2000	2001
technolog	1.96	4	2014	2017	machin	2.43	1	2018	2018
process	1.95	4	2012	2015	emot	1.58	1	2016	2016
model	2.1	4	2008	2011	institut	1.81	1	2017	2017
spatial	1.95	4	2012	2015	fethic	1.56	1	2018	2018
cognit	1.71	4	2010	2013	autonom	2.18	1	2008	2008
languag	1.65	4	2002	2005	biolog	1.99	1	2008	2008
analysi	2.11	3	2018		human	1.52	1	2016	2016

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