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Formalisms of digital technology affordances

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Formalisms of Digital Technology Affordances

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A research report submitted to the Faculty of Commerce, Law, and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in the field of Digital Business

Johannesburg, 2020

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ABSTRACT

The extant literature does not sufficiently problematise the underlying structural elements and causal mechanisms of '*feature'* and '*ability'* constructs in the emergence of *affordances*. An explanatory, concrete *critical realist* artefact-based case study involving a smartphone digital device was conducted. The study sought to explore the underlying structural elements and causal mechanisms of '*feature'* and '*ability'* constructs in the emergence of *affordances*. The study was limited to the Chemero (2003) and Şahin et al., (2007) relational *feature-ability* conception of affordances (i.e. agent affordance perspective), with particular focus on digital technology affordances.

Eight plausible causal explanations were *retroduced* from the underlying structural elements of the *feature* and *ability* constructs, in the affordance actor-artefact relation. Out of the eight, two causal explanations were found to be atypical of affordance causal logic, in the traditional IT sense of the *elementary interaction loop*. However, in the context of digital technologies, these atypical causal mechanisms were found to be plausible. This is because digital technologies can support advanced actor-artefact communicative interactions, transcending *space*, *time*, *actor*, and *artefact* dimensions (e.g. *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, *verbal*, etc.).

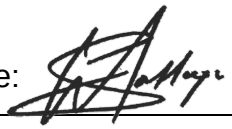
The study showed through retroductive causal explanatory logic, that affordances are emergent constructs of the underlying *conditional-causal-structure* relations of '*feature'* and '*ability'* constructs and their combined *feature-ability mechanism* elements. Furthermore, a typology of digital technology affordance causal mechanisms, as well as the revised affordance formalisms were proposed.

KEYWORDS

Ability, affordance, digital technology, direct causality, experiential computing, feature, material, mechanism, social, sociomateriality

DECLARATION

I, **SAMUEL MAHLANGU**, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Digital Business at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: **SAMUEL MAHLANGU** Signature: 

Signed at: **JOHANNESBURG**

On the **30th** day of **March 2020**

Final Revision **05th** day of **October 2020**

DEDICATION

This research is conducted at a time when the nations of the world are confronted with the scourge of the ‘severe acute respiratory syndrome coronavirus disease of 2019’ (SARS- COVID-19) or COVID-19. A very long name for a microbe if one may ask.

This work is dedicated to the resiliency of the human spirit, and the fortitude of all those practitioners who are fighting at the frontline of the COVID-19 pandemic trying to save lives.

My family, friends, and colleagues (elsewhere), thank you for all the support and understanding throughout the journey.

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A special thanks to my supervisor Dr Yvonne Saini, for allowing me space and latitude to explore and learn. It was a worthwhile journey of discovery.

To Prof Brian Armstrong, thank you for seeing the bigger picture and providing the necessary guidance at the beginning of this journey, it really helped.

Thank you to Ayanda Magida for the motivation, the readiness and promptness to support, and the kind considerations for the students in this first cohort. You made the journey much less arduous.

To staff and colleagues at the Wits Business School, especially that group of the very first cohort of the Master of Management in Digital Business (MMDB), thank you for your support and travelling this journey together.

TABLE OF CONTENTS

ABSTRACT ..... **ii**

DECLARATION ..... **iii**

DEDICATION ..... **iv**

ACKNOWLEDGEMENTS ..... **v**

TABLE OF CONTENTS ..... **vi**

LIST OF TABLES ..... **ix**

LIST OF FIGURES ..... **x**

LIST OF ACRONYMS ..... **xi**

LIST OF FORMULAS ..... **xii**

CHAPTER 1. INTRODUCTION **1**

1.1 PURPOSE OF THE STUDY 1
1.2 CONTEXT OF THE STUDY 2
1.2.1 DIGITALISATION 2
1.2.2 SOCIOMATERIALITY 3
1.2.3 AFFORDANCES 4
1.3 RESEARCH PROBLEM 4
1.4 RESEARCH OBJECTIVES 6
1.5 SIGNIFICANCE OF THE STUDY 7
1.6 DELIMITATIONS OF THE STUDY 8
1.7 DEFINITION OF TERMS 10
1.8 ASSUMPTIONS 16

CHAPTER 2. LITERATURE REVIEW **18**

2.1 INTRODUCTION 18
2.2 DEFINITION OF TOPIC OR BACKGROUND DISCUSSION 18
2.3 WHAT IS ABILITY? 20
2.3.1 ABILITY LOGIC 20
2.3.2 SOCIAL BEHAVIOUR 21
2.3.3 ABILITY DESCRIPTION 21
2.3.4 PROPOSITION 1: ABILITY STRUCTURAL ELEMENTS 25
2.4 WHAT ARE FEATURES? 26

2.4.1 Features overview 26
2.4.2 Feature affordances 27
2.4.3 Functional features 28
2.4.4 Proposition 2: Feature structural elements 29
2.5 Affordances 30
2.5.1 Affordance continuum 30
2.5.2 Affordance formalism 32
2.5.3 Proposition 3: Affordance emergence 34
2.6 Conclusion of Literature Review 35

CHAPTER 3. RESEARCH METHODOLOGY 38

3.1 Research approach 38
3.1.1 Meta-reality 38
3.1.2 "Sceptic-reality" 40
3.1.3 Critical realism 41
3.1.4 Causal reality 43
3.2 Research design 45
3.2.1 Research type 45
3.2.2 Research method 47
3.2.3 Research procedure 48
3.3 Data collection methods 50
3.4 Research instrument 50
3.5 Procedure for data collection 51
3.6 Data analysis and interpretation 52
3.7 Limitations of the study 52
3.8 Transferability and dependability 53
3.8.1 Transferability 53
3.8.2 Credibility 53
3.8.3 Dependability 54
3.9 Demographic profile of respondents 55
3.10 Ethical considerations 55

CHAPTER 4. PRESENTATION OF FINDINGS 56

4.1 Introduction 56
4.2 Ability structural elements 57
4.3 Feature structural elements 58
4.4 Affordance emergence 58
4.5 Summary of the findings 61

CHAPTER 5. DISCUSSION OF THE FINDINGS 62

5.1 Introduction 62
5.2 Explication of events 63
5.2.1 Case context 63
5.2.2 Case scenarios 64
5.2.3 Case framing 65

5.2.4 CASE DESIGN 67
5.3 EXPLICATION OF STRUCTURE AND CONTEXT 68
5.3.1 SOCIAL STRUCTURE 69
5.3.2 MACRO STRUCTURE 71
5.3.3 MICRO STRUCTURE 74
5.3.4 MICRO-INTERACTIONS 77
5.4 RETRODUCTION 80
5.4.1 CAUSAL EXPLANANDA 80
5.4.2 CAUSAL EXPLANANS 82
5.4.3 CAUSAL ASSUMPTIONS 83
5.5 EMPIRICAL CORROBORATION 85
5.5.1 CAUSAL RELEVANCE 85
5.5.2 CAUSAL MECHANISMS 88
5.5.3 INDIRECT MECHANISMS 89
5.5.4 DIRECT MECHANISMS 91
5.5.5 CAUSAL PLAUSIBILITY 93
5.5.6 CAUSAL CONSIDERATIONS 96
5.6 CONCLUSION 98
5.6.1 AFFORDANCE CAUSAL LOGIC 98
5.6.2 AFFORDANCE CAUSAL MECHANISMS 99
5.6.3 AFFORDANCE REVISED FORMALISM 100

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS 102

6.1 INTRODUCTION 102
6.2 ABILITY 102
6.2.1 ABILITY STRUCTURAL ELEMENTS 102
6.2.2 ABILITY CAUSAL MECHANISMS 103
6.3 FEATURES 103
6.3.1 FEATURE STRUCTURAL ELEMENTS 104
6.3.2 FEATURE CAUSAL MECHANISMS 104
6.4 AFFORDANCES 105
6.5 RECOMMENDATIONS 107
6.6 SUGGESTIONS FOR FURTHER RESEARCH 108

REFERENCES 109

LIST OF TABLES

Table 1 Behaviour instantiations 22

Table 2 Critical realist research method procedures 48

Table 3 Causal factor evaluation criteria 54

Table 4 Experiential computing communicative interactions 64

Table 5 Smartphone communicative interactions 92

Table 6 Theoretical corroboration of causal explanations 95

LIST OF FIGURES

Figure 1 Affordance research conceptual framework 1

Figure 2 Research objectives and questions 6

Figure 3 Agency social practice 23

Figure 4 Affordance actualisation continuum 30

Figure 5 Outline of critical realist ontology 43

Figure 6 Typical causal explanation structure 44

Figure 7 Critical realist research types 46

Figure 8 Critical realist research methods 47

Figure 9 The situated affordances in a sociomaterial routine 67

Figure 10 Macro-micro mechanism-based structure 70

Figure 11 Macro-micro mechanism-based structural transformations 71

Figure 12 Socio-technical, social, and sociomaterial systems 72

Figure 13 Morphogenetic model of technology emergent use behaviour 73

Figure 14 Experiential technology-user interactions 76

Figure 15 Theoretical re-description of feature and ability 78

Figure 16 Retroduction of plausible causal explanations 82

Figure 17 Retroduced plausible causal explanations 86

Figure 18 Direct and indirect affordance plausible causal explanations 88

Figure 19 Theoretical plausibility of retroduced causal mechanisms 94

LIST OF ACRONYMS

A_F	Action parameter of the technology component entity Ex_F in the feature specification (A_F, R_F, O_F, Pr_F, Ex_F)
A_S	Achievement or accomplishment parameter in the ability specification (W_S, K_S, KH_S, P_S, A_S)
Ce_n	Affordance causal explanation of the form: event E_N is caused by mechanism M_N of structure S_N, under specified conditions C_N
Ex_F	Entity parameter of the technology component entity responsible for executing the action A_F in the feature specification (A_F, R_F, O_F, Pr_F, Ex_F).
KH_S	the *know-how* KH_S knowledge parameter in the ability specification (W_S, K_S, KH_S, P_S, A_S)
K_S	the cognition parameter in the ability specification (W_S, K_S, KH_S, P_S, A_S)
O_F	Object parameter of the object used in the execution of the action A_F by the technology component entity Ex_F in the feature specification (A_F, R_F, O_F, Pr_F, Ex_F).
Pr_F	Precondition parameter or contextual conditions within which execution of the action A_F by the technology component entity Ex_F in the feature specification (A_F, R_F, O_F, Pr_F, Ex_F) happens.
P_S	*procedural dexterity* parameter in the ability specification (W_S, K_S, KH_S, P_S, A_S)
R_F	result achieved parameter or accomplished by the technology component entity Ex_F when executing action A_F under the contextual conditions Pr_F using or involving object O_F in the feature specification (A_F, R_F, O_F, Pr_F, Ex_F).
TFM	topological functioning model of functional features
W_S	*motivation* parameter in the ability specification (W_S, K_S, KH_S, P_S, A_S)

LIST OF FORMULAS

(i)	*affordance* = *affords*-**ϕ** (*features*, *ability*)	[Aff1]
(ii)	*agent affordance* = (*effect*, (*entity*, *behaviour*))	[Aff2]
(iii)	*environment affordance* = (*effect*, (*agent*, *behaviour*))	[Aff3]
(iv)	*observer affordance* = (*effect*, (*agent*, (*entity*, *behaviour*)))	[Aff4]
(v)	*affordance* = (*object*, *action*, *effect*)	[Aff5]
(vi)	*affordance* = *(actor, object, action, effect)*	[Aff6]
(vii)	*Sociomaterial routine = (A, Actor, L, M, Aff, Art, Df)*	[Sr1]
(viii)	*Behaviour* = <IA> = < I, W, K, KH, P, A, PC, S >	[Bh1]
(ix)	*Ability = (W, K, KH, P, A)*	[Bh2]
(i)	*Activity = (K, KH, P, A)*	[Bh3]
(ii)	*Attempt = (W, K, KH, P)*	[Bh4]
(iii)	*feature = (R, W, S)*	[Ff1]
(iv)	*functional feature* = (*A, R, O, Pr, E*),	[Ff2]

CHAPTER 1. INTRODUCTION

This chapter outlines the purpose and significance of the research by briefly describing the nature of the problem, the context, the objectives, as well as the assumptions applicable to the study.

1.1 Purpose of the study

The extant literature does not sufficiently problematise the underlying structural elements and causal mechanisms of '*feature'* and '*ability'* constructs in the emergence of *affordances*. The purpose of this research is thus, to explore the underlying structural elements of '*feature'* and '*ability'* constructs and explain their causal mechanisms in the emergence of *affordances* (Chemero, 2003; Şahin et al., 2007; Stoffregen, 2003). The study will put particular emphasis on *digital technology affordances* (Autio et al., 2018; Nambisan et al., 2017; Yassaee & Winter, 2017). Affordance(s) have been conceptualised as *relational* constructs between what the *features* of the environment afford the *agent* (actor) and the *ability* of the *agent* (actor) to exploit those *feature* provided possibilities (Figure 1) (Chemero, 2003).

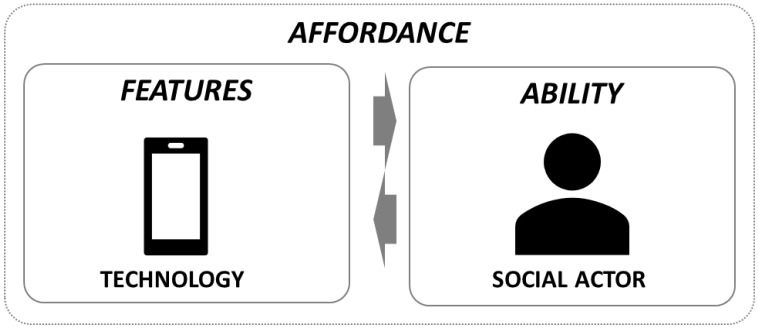


Figure 1 Affordance research conceptual framework

Affordances are "the potential for *behaviours* associated with achieving an immediate *concrete outcome* and arising from the *relation* between an *artefact* and a *goal-oriented actor or actors*" (Strong et al., 2014, p. 69). Thus, affordances involve *behaviour* possibilities from *artefact-actor* relations (Strong et al., 2014). The concepts of *artefact* or *entity* are used synonymously with *features* and similarly with *behaviour* and *ability* (Chemero, 2003; Şahin et al., 2007). Despite the various conceptualisation

of the affordance construct, the *features*, and *abilities* whether explicit or implied are relatively consistent in the extant literature (Andries et al., 2018; Cakmak et al., 2007; Şahin et al., 2007; Stoffregen, 2003; Yamanobe et al., 2017; Zech et al., 2017). However, the underlying elements of these *features* and *ability* concepts have received limited attention in the extant affordance studies. That is, what aspects of *features* or *ability* are affordance causal mechanisms (Bygstad et al., 2016).

The current study involves a *critical realist* enquiry in a form of an explanatory case study of an engaged user (social actor) of digital technology (Carlsson, 2012; Easton, 2010; Mingers, 2004; Mingers et al., 2013; Okoli, 2015b, 2015a; Ononiwu et al., 2018; Ononiwu & Brown, 2013; Raduescu & Vessey, 2009; Rycroft-Malone et al., 2012; Tsang, 2014; Wang et al., 2016; Wynn & Williams, 2012). The study takes a *critical realist* stance to explore the *causal mechanisms* of affordances within and between the *feature*, and *ability* concepts (Bygstad et al., 2016; Leonardi, 2013a; Volkoff & Strong, 2017; Wynn & Williams, 2012). The outcome of the enquiry is to formulate the theoretical propositions of the causal mechanisms of the affordance *feature*s and *ability* concepts (Strong et al., 2014; Volkoff & Strong, 2013, 2017).

1.2 Context of the study

The purpose of this research is to explore the underlying elements of ***features*** and ***ability*** concepts in the affordance formalism (Cakmak et al., 2007; Şahin et al., 2007; Stoffregen, 2003; Zech et al., 2017). The study is a critical realist account (Wynn & Williams, 2012) to explore the underlying causal mechanisms (Markus & Robey, 1988; Markus & Rowe, 2018; Markus & Silver, 2008) of *ability* and *feature* concepts in the emergence of affordances (Volkoff & Strong, 2013, 2017). The context of the study is *digital technology affordances* in digital technology use situations (Autio et al., 2018; Nambisan et al., 2017; Yassaee & Winter, 2017).

1.2.1 *Digitalisation*

Digital infrastructures are essentially IT artefacts, albeit of a special kind (Tilson et al., 2010). Digitalization involves the application of *digital technologies* to social contexts, whilst *digitizing* involves technology conversions from analogue to *digital* (Tilson et al., 2010). Digitalisation for instance, as the simultaneous digitalising of both users (i.e.

digital personas) and infrastructure (i.e. digital infrastructure such as devices, computing, etc), has been argued to be a form of *sociomateriality* (Thambusamy & Nemati, 2011).

Digital technologies (Berger et al., 2018) are technical artefacts and their use by social actors, can be explained through *sociomateriality* (Leonardi, 2012, 2013a; Orlikowski, 2007; Orlikowski & Scott, 2008; Thambusamy & Nemati, 2011). Digital technologies cover a broad spectrum of technologies ranging from *platform* technologies*, connectivity* technologies*, actor-based product* technologies*, sensor-based data collection* technologies*, analytical insight generation* technologies*, analytical interaction* technologies*,* and *augmented interaction* technologies (Berger et al., 2018). Digital technologies are also *programmable*, *addressable*, *senseable*, *communicable*, *memorizeable*, *traceable*, and *associable* (Yoo, 2010).

1.2.2 *Sociomateriality*

Sociomateriality is a theoretical lens of perceiving the constitutive reciprocity of the *material* (technology) and the *social* (Faraj & Azad, 2012; Leonardi, 2013a; Orlikowski, 2007; Thambusamy & Nemati, 2011). *Sociomateriality* is a theoretical lens through which to perceive the material in social use settings (Orlikowski, 2007; Orlikowski & Scott, 2008). As a construct, *sociomateriality* advocates that the study of technical artefacts should not be considered in isolation of the societal contexts of their use (Orlikowski, 2007; Orlikowski & Scott, 2008). *Sociomateriality* is the *entanglement* (Orlikowski, 2006, 2007) or the *imbrication* (Leonardi, 2011) of the *social* and the *material* (Leonardi, 2011, 2012, 2013a).

Sociomaterial practices (Gaskin et al., 2014; Orlikowski, 2007), are spaces within a broader *socio-technical system* (Leonardi, 2012), where the *social* and *material* are *entangled* (Orlikowski, 2006, 2007) or *imbricated* with each other (Leonardi, 2011, 2012, 2013a). *Sociomaterial practices* (Orlikowski, 2007) are composed of *sociomaterial routines* (Gaskin et al., 2014). *Sociomaterial routines* are purposeful interactions of interrelated activities involving social and material elements within a *sociomaterial practice* (Gaskin et al., 2014; Leonardi, 2011). *Sociomaterial routines* are constituted of *activities* each involving a distinct social actor(s), using the material tool, affording certain affordances for a particular purpose (Gaskin et al., 2014).

Sociomaterial routines can be formalised as follows (see formula [SR1]), where activity type ***A***, actor configuration ***Actor***, *activity location* ***L****; tool modality* ***M****, tool affordance* ***Aff****, artefact type* ***Art****, and dataflow* ***Df****, are generative elements of the sociomaterial routine* (Gaskin et al., 2014):

Sociomaterial routine = (***A***, ***Actor***, ***L***, ***M***, ***Aff***, ***Art***, ***Df***) [Sr1]

Given the *sociomaterial routine* formulation above (see formula [Sr1]), affordances are thus located in *sociomaterial routines* (Gaskin et al., 2014) which are spaces of *social* and *material entanglements* (Orlikowski, 2006, 2007) or *imbrication* (Leonardi, 2011, 2012, 2013a).

1.2.3 *Affordances*

Affordances are aspects of *sociomateriality* (Bloomfield et al., 2010; Fayard & Weeks, 2014; Gasson, 2012; Kautz & Jensen, 2012; Leonardi, 2011, 2012, 2013a; Orlikowski, 2007; Pentland et al., 2012; van Dijk & Rietveld, 2017; Van Osch & Mendelson, 2011; Volkoff & Strong, 2017). Affordances are a way of contextually conceptualising the action possibilities that the *material* (i.e. technology) "affords" to *social* actors (Fayard & Weeks, 2014; Pozzi et al., 2014). Affordances are relational constructs (Chemero, 2003) providing possibilities for action (Bernhard et al., 2013; Markus & Silver, 2008). Affordances are thus sociomaterial action possibilities (Cabiddu et al., 2014; Faraj & Azad, 2012; Van Osch & Mendelson, 2011). In terms of *sociomateriality*, it is not sufficient to only consider what features technology provides, but also whether the social actors can perceive and leverage such features (Anderson & Robey, 2017).

1.3 Research problem

The extant literature does not sufficiently problematise the underlying structural elements and causal mechanisms of '*feature'* and '*ability'* constructs in the emergence of *affordances*. For instance, where *features* are considered, they are rather treated as descriptive aspects of technology artefacts and not as constructs for explication (Cheikh-Ammar, 2018; Griffith, 1999; Karahanna et al., 2018; Leonardi, 2013b; Lim & Kim, 2009; Markus & Silver, 2008; Sjöström a & Ågerfalkb, 2005; Yan et al., 2013). The *ability* concept, on the other hand, is cursorily treated as a means to the desired

outcomes (Bernhard et al., 2013; Chemero, 2003; Stoffregen, 2003), and not as a problematic concept for explication. The ability concept is loosely appropriated as a taken for granted and implied "-***ability***" suffix, such as climb-***ability***, read-***ability***, etc., and not as a problematised construct for appropriate explication (Chemero, 2003; Stoffregen, 2003).

For instance, the extant reviewed literature describes affordances as *relational* and *temporal* (Chemero, 2003; Lanamäki et al., 2016), *contextual* (Anderson & Robey, 2017; Fayard & Weeks, 2014; Turner, 2005), and realised over an *actualisation continuum* (Bernhard et al., 2013; Pozzi et al., 2014). True affordances as in *affordances qua affordance* are the variable link between the features and outcomes or feature-outcome link (Evans et al., 2017). As a consequence of these varied conceptions of affordances, the antecedents *of afforded behaviour* are still elusive in the extant text (Tillas et al., 2017; Withagen et al., 2012), and the definitional confusion of the *affordance* concept persists (Davis & Chouinard, 2017).

However, there is also reasonable consensus that, in terms of the *agent affordance perspective* (Cakmak et al., 2007; Şahin et al., 2007), what is key to the notion of affordances are the *features* of the environment and the *ability* of the animal to perceive and leverage such features (Brown & Maier, 2015; Chemero, 2003). That is, it is apparent that the *feature-ability* construct (Brown & Maier, 2015; Chemero, 2003) or the *entity-behaviour* tuple construct (Cakmak et al., 2007; Şahin et al., 2007) reasonably conceptualises the affordance construct adequately. However, what is not apparent, is how these two paired constructs relate to creating affordances or dis-affordances (constraints) (Majchrzak & Markus, 2013).

Given the context, and appropriate stage of affordance actualisation continuum, affordances are still about relations between the *features* and the *ability* of the users (Bernhard et al., 2013; Pozzi et al., 2014). That is, users need to have the *ability* to perceive, use, and experience the effects of *features* as affordances (Bernhard et al., 2013; Pozzi et al., 2014). Thus, it is not sufficient to only consider what *features* technology provides, but also whether the social actors can perceive and leverage such features (Anderson & Robey, 2017; Markus & Silver, 2008).

It is proposed that to contribute in explicating technology-user relations as well as how technology affects its users and its utilisation (Lanamäki et al., 2016), the appropriate and accurate conceptualisation of affordances is essential. That is, what are the underlying elements of both these feature and ability constructs, and how do they contribute to the affordance construct.

1.4 Research objectives

To conceptualise the nature of the *feature-ability* construct, a review of extant literature will be conducted. The goal is to explore the elements of both ***features*** and ***abilities*** *or* more appropriately ***user abilities*** in the context of *digital technology affordances* (Autio et al., 2018; Crosby et al., 2019; Ranker, 2015; Yassaee & Winter, 2017). The mechanisms and logic of user abilities, as well as how they are enacted or actualised and their relationship to technology features, will also be explored. Thus, the following research questions will guide this study (see Figure 2):

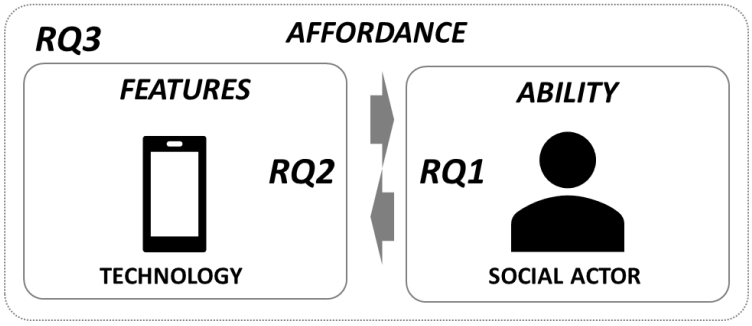


Figure 2 Research objectives and questions

- (**RQ1**): What are the underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances*?
- (**RQ2**): What are the underlying structural elements and causal mechanisms of the '*feature'* construct in the emergence of *affordances*?
- (**RQ3**): How do *affordances* emergence from the underlying structural elements and causal mechanisms of the '*feature'* and '*ability'* constructs?

The study will focus on Chemero's (2003) formulation of the affordance construct (see formula [Aff1]). Chemero's (2003) formulation of the affordance construct corresponds

to the *agent perspective* of the Şahin et al., (2007) affordance formulation. Furthermore, the *features* and *ability* elements in Chemero's (2003) formulation respectively corresponds to the *entity* and *behaviour* elements in the Şahin et al., (2007) affordance formulation.

Affordances as relational constructs (Chemero, 2003) or behavioural predispositions (Tillas et al., 2017; Withagen et al., 2012) or conditional causal mechanisms (Davis & Chouinard, 2017) are useful constructs to explain the effects of technological artefacts is social use settings (Bernhard et al., 2013; Pozzi et al., 2014). However, the nature of artefact *feature* causality on the afforded behaviour still requires explication — that is, *what of the artefact feature* or *what aspect of the artefact*, is '*the affecting what'* of *behaviour* and in which way.

1.5 Significance of the study

Affordances as relational constructs (Chemero, 2003) or behavioural predispositions (Tillas et al., 2017; Withagen et al., 2012) or conditional causal mechanisms (Davis & Chouinard, 2017) are useful constructs to explain the effects of technological artefacts in social use settings (Bernhard et al., 2013; Pozzi et al., 2014). However, the relational nature of the *feature-ability* construct in digital technology affordances is less problematised in the extant literature. Thus, through formally clarifying the relational nature of the *feature-ability* construct and its underlying actualising mechanisms, it is proposed that such clarity might enhance the understanding of affordances and perhaps reduce the extant definitional confusion of affordance (Davis & Chouinard, 2017).

1.6 Delimitations of the study

The current study involves exploring the conditional causal mechanisms (Davis & Chouinard, 2017) between user abilities and digital technology features (Chemero, 2003). The key focus of the study is the nature of the *feature-ability* construct as it relates to affordances in the context of *digital technology* and by extension digital technology affordances.

Furthermore, affordances have also been conceptualised and formalised as: (a) *causal relation* mechanisms (Steedman, 2002), (b) properties of the *animal–environment* system (Stoffregen, 2003), (c) outcome of environmental *feature* and animal *ability* or *feature–ability* relations (Chemero, 2003), (d) *feature-ability* relations in an *animal–environment* system (i.e. *animal–feature–ability* system) (Cakmak et al., 2007; Şahin et al., 2007); and (e) the *object–effect–action* triad in robotics (Andries et al., 2018; Atıl et al., 2010; Dag et al., 2010; Kammer et al., 2011; Lopes et al., 2007; Min et al., 2016; Moldovan et al., 2018; Montesano et al., 2008, 2009). In summary affordances have been formalised from the following perspectives:

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]
agent affordance = (*effect*, (*entity*, *behaviour*)) [Aff2]
environment affordance = (*effect*, (*agent*, *behaviour*)) [Aff3]
observer affordance = (*effect*, (*agent*, (*entity*, *behaviour*))) [Aff4]
affordance = (*object*, *action*, *effect*) [Aff5]
affordance = *(actor, object, action, effect)* [Aff6]

However, for purposes of the current study, which is to explore the affordances of digital technology, the relevant affordance formulation is limited to the following (see formula [Aff1]):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

The focus of the current study is on the *feature* (*entity*) and *ability* (*behaviour*) constitutive constructs of affordances (Chemero, 2003; Şahin et al., 2007). The *ability* and *feature* conceptions are limited to the five-parameter *ability* construct: *(W, K, KH, P, A)* (Ossorio, 2010, pp. 33–43, 53), and the five-parameter *feature* construct (*A, R, O, Pr, E*) (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

Other conceptions of feature such the Classen et al. (2008, p. 21) conception (see formula [Ff1]) as well as the extended functional feature specification (see formula [Ff3]) are excluded from the current study (Osis & Donins, 2017, p. 123; Solomencevs, 2016). This because the extended twelve-parameter (*Id, **A**, Op, **R**, **O**, Cl, St, **Pr**, Ps, **E**, Es, S*) and the five-parameter (*A, R, O, Pr, E*) descriptions are considered to be essentially the same, in terms of the objectives of the current study. That is, the additional variables in the extended specifications are not contributing to the objectives of the current study.

Ability or behaviour conception likewise is limited to the five-parameter *ability* construct: *(W, K, KH, P, A)* (Ossorio, 2010, pp. 33–43, 53). The other behaviour conceptions such as the intentional action (see formula [Bh1]), a*ctivity description* (see formula [Bh3]), and a*ttempt description* (see formula [Bh4]), are excluded from the current enquiry.

1.7 Definition of terms

Term	Definition
Ability	Experiential knowledge to intentionally accomplish something by *procedural dexterity*, under the specified *state of affairs* (Alter, 2001; Cath, 2009; Ossorio, 2010, pp. 33–43, 53).
Affordance	Relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013).
Causal Metaphor	Indirect social causality where technology involvement is implied figuratively (Markus & Rowe, 2018).
Causal Misnomers	Indirect social causality where technology involvement is implied when it is actually not involved (Markus & Rowe, 2018).
Chronemics	Time-based or timing based communicative interactions (Saunderson & Nejat, 2019)
Critical naturalism	the *transcendental* and *dialectical* notions of society as both an emergent relational outcome and predisposing condition of human agency, useful to explain dichotomies and contradictions in society (Archer et al., 1998, pp. xiii–xvii).
Critical realism	the *transcendental* (i.e. *intransitive*, *transfactual*, *stratified*) conception of social existential reality as well as the dialecticisation (i.e. dialectical critique) of concepts such as non-identity; negativity and absences; totality and holistic causality; including transformative agency and praxis (Archer et al., 1998; Hartwig, 2015).
Detectables	the sorts of existential things that (circumstances permitting) cannot be sensed but can be detected using other means (Chakravartty, 2007, pp. 3–26).

Term	Definition
Dialectical critical realism	the dialecticisation of concepts such as: (a) structure, differentiation, change, emergence (roughly corresponding to *transcendental realism* or non-identity); (b) *negativity* and *absences (i.e. absenting* of *constraints* on *social ills*); (c) *totality* and *holistic causality*; and (d) transformative agency and praxis, etc. (Archer et al., 1998, pp. xix–xxiv; Hartwig, 2015, pp. 130–138).
Digital Technology	Technologies implementing the experiential computing paradigm wherein users can interact with the technology through space, time, actor, and artefact dimensions involving perceptual, motor-activity, functional, and/or purposive experience (Yoo, 2010)
Digital Technology Affordances	Relational action potentials for achieving concrete outcomes between goal-directed actors involving digital technologies (Volkoff & Strong, 2013).
Digitalism	the phenomenon where every aspect of society is impacted by digital technologies or digital transformations and the culture of digital technology usage (digitality) is entrenched (Bowen & Giannini, 2014).
Digitality	The social culture where the use of digital technologies is entrenched (Bowen & Giannini, 2014) (see also digitalism)
Direct Causality	The emergent mechanism involving the social and material structural conjunctures actively involved in the generative causation of events (see mechanism causality).
Direct Mechanism	The emergent mechanism involving the social and material structural conjunctures actively involved in the generative causation of events (see direct causality) (Markus & Rowe, 2018).

Term	Definition
Entity realism	the philosophical stance supporting the existential reality of entities described by theories, but scepticism about such theories (Chakravartty, 2007, pp. 27–33).
Epistemic structural realism	the philosophical stance supporting the existential reality of the structural aspects of reality, but scepticism about the nature of such entities (Chakravartty, 2007, p. 34).
Experiential Computing	Computing paradigm involving perceptual, motor-activity, functional, and/or purposive experiential technology-user interactions, that are experienced or manifested through space, time, actor, and artefact dimensions (Yoo, 2010).
Explanatory critique	the *cognitive critique* (i.e. cognitive *explanatory critique*) and *ethical critique* (i.e. needs-based *explanatory critique*) of social ills and their causal antecedents (e.g. structure, beliefs, values, etc.), through the application of *explanatory critical reason* (i.e. a type of *ethical naturalism*) (Archer et al., 1998, pp. xvii–xix, 387; Hartwig, 2015, pp. 196–201).
Feature	A component technology entity that can achieve *results*, by executing an *action*, involving or using action linked *object*, under specified *preconditions* (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).
Functional Feature	A component technology entity that can achieve *results*, by executing an *action*, involving or using action linked *object*, under specified *preconditions* (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016) (see also feature)
Haptics	Communicative tactility or touch-based communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019

Term	**Definition**
Imbrications	the reciprocal affecting of the *social* agency and the *material* agency (e.g. technology artefacts) in sociomaterial encounters (Leonardi, 2011, 2012, 2013a).
Indirect Causality	A*synchronous indirect* actor-artefact causal interactions where either party in the actor-artefact interaction individually and/or independently generates events which are also independently responded to by the other interacting party in the interaction.
Kinesics	Body movements, gestures, positions, gazes, and appearances related to communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019)
Material Event	An outcome or event generated by an artefact or material agency (Leonardi, 2011, 2012, 2013a)
Material Mechanism	the mechanism that an artefact or material agency uses to generate the material event or outcome (Leonardi, 2011, 2012, 2013a)
Materiality	"The arrangement of an artefact's physical and/or digital materials into particular forms that endure across differences in place and time and are important to users" (Leonardi, 2012, pp. 42)
Mechanism Causality	The emergent mechanism involving the social and material structural conjunctures actively involved in the generative causation of events (see direct causality)
MELDARA or ontological-axiological chain	the seven dimensions of being in the philosophy of *meta-reality* (PMR) defined as: 7**A**>6**R**>5**A**>4**D**>3**L**>2**E**>1**M**, where *first moment* (1**M**); *second edge* (2**E**); *third level* (3**L**); *fourth dimension* (4**D**); *fifth aspect* (5**A**); *sixth realm* (6**R**); and *seventh awakening* (7**A**) are ontological dimensions and where each

Term	Definition
	higher dimension preservatively contains the lower (Bhaskar, 2008a, pp. ix–xx)
Meta-reality	Existential reality of the sorts of things that (circumstances permitting) can be sensed unaidedly (i.e. *observables*), and those that cannot (i.e. *unobservables*) (Chakravartty, 2007, pp. 3–26).
Observables	the sorts of existential things that (circumstances permitting) can be sensed unaidedly (Chakravartty, 2007, pp. 3–26).
Oculesics	Eye kinesics or eye behaviours, gazes and other communicative interactions based on ocular expression (Singh, 2011)
Ontic structural realism	the philosophical stance perceiving structures as ontological classes *sui generis*, and also non-reducible to underlying relational entities (Chakravartty, 2007, p. 34).
Philosophy of meta-reality (PMR)	The philosophical system consisting of: (a) *transcendental realism* (TR); (b) *critical naturalism* (CN); (c) the theory of *explanatory critiques* (EC); (d) *dialectical critical realism* (DCR); and (e) *transcendental dialectical critical realism* (TDCR) (Bhaskar, 2008a, pp. ix–xx).
Proxemics	Hans & Hans, 2015; Saunderson & Nejat, 2019; Singh, 2011
Retroduction	The proposition of plausible and verifiable causal linkages to observed phenomena (Wynn & Williams, 2012),
Scientific realism	The philosophical stance supporting the existential reality of the *observables* and most of the *unobservables* posited by scientific theories (Hartwig, 2015, pp. 397–400), which also posits that “scientific theories correctly describe the nature of a mind-independent world” (Chakravartty, 2007, p. 4).

Term	Definition
Semirealism	the philosophical stance supporting the existential reality of concrete structures and their causal contact to the world through their detection properties, but scepticism about their auxiliary properties (Chakravartty, 2007, pp. 39–48).
Social Event	An outcome or event generated by the social agency (Leonardi, 2011, 2012, 2013a)
Social Mechanism	the mechanism that the social agent employs in accomplishing or generating a social event (Leonardi, 2011, 2012, 2013a)
Sociomaterial Event	An outcome or event generated by the integrated mechanism involving the social and material agencies (Leonardi, 2011, 2012, 2013a)
Sociomaterial Mechanism	The integrated mechanism involving the social and material agencies use to accomplish sociomaterial events (Leonardi, 2011, 2012, 2013a)
Sociomaterial Routines	the respective goal-directed activities of the social and material agencies in sociomaterial encounters (Leonardi, 2011, 2012, 2013a).
Sociomateriality	the conceptualisation of the reciprocal affecting of the *social* agency and the *material* agency (Leonardi, 2011, 2012, 2013a).
Structural realism	the philosophical stance supporting the existential reality of the structural relations among entities described by theories, but scepticism about the existential reality of such entities (Chakravartty, 2007, pp. 27–33).
Textual	Text-based (e.g. Command prompt) communicative interactions (Feine et al., 2019)

Term	Definition
Transcendental realism	the notion of existential reality of concrete structures and entities with real causal contacts in a mind-independent real-world, which is *intransitive*, *transfactual*, and *stratified*, and upon which the truth value of extant and novel theories is premised (Archer et al., 1998, pp. x–xiii; Bhaskar, 2008a, pp. x–xii; Hartwig, 2015, p. 474).
Undetectables	the sorts of existential things that cannot be sensed nor detected by available means (Chakravartty, 2007, pp. 3–26).
Unobservables	the sorts of existential things that (circumstances permitting) cannot be sensed unaidedly including (Chakravartty, 2007, pp. 3–26).
Vocalics/ Verbal	Vocal intonations and auditory vocalisation based communicative interactions (Feine et al., 2019)

1.8 Assumptions

The study is based on the narrative synthesis of the reviewed *affordances*, *features* and *abilities* extant literature (Juntunen & Lehenkari, 2019; Paré et al., 2015; Schryen et al., 2020). The formalisms of *affordances features*; and *abilities* form the foundational background to the study (Chemero, 2003; Şahin et al., 2007; Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016; Ossorio, 2010, pp. 33–43, 53).

The current research explores the affordance *feature-ability* or the actor-artefact relation in the formulation (see formula [Aff1]):

$$affordance = affords\text{-}\phi\ (features, ability) \qquad [Aff1]$$

In terms of the retroductive aspects of the research the following assumptions are deemed applicable in the context of the retroduced scenarios:

(i) The critical realist assumptions are wholly assumed, and that is (Wynn & Williams, 2012):

a) reality exists independent of empirical observation (independent existence of reality);
b) reality is comprised of events, and experiences that are caused by causal mechanisms of entities and structures in the *real* domain of stratified reality;
c) observed reality is an outcome of stratified emergence (i.e. hierarchical bottom-up causation), albeit not necessarily reducible hierarchically

(ii) The macro-macro, macro-micro, micro-micro micro-macro typology of social mechanisms is assumed in the context of features, ability, and affordance elements (Coleman, 1994; Hedström & Ylikoski, 2010; Matsueda, 2017; Mayntz, 2004; Ononiwu & Brown, 2013).

(iii) The feature-ability relation does not involve *actor-artefact-actor* interactions. Thus, the *actor-artefact-actor* interactions are *explicitly excluded* among the cases.

(iv) It is assumed the artefacts have *independent causal agency* and are capable of *independent interaction* with the social agency. Albeit it is conceded that all the material entities are artificial and thus human-designed, created, and/or operated.

(v) It is assumed affordances include instances of unprovoked technology afforded outcomes or instance where an automated artefact independently generates an outcome on behalf of the social actor physically unprovoked.

(vi) It is assumed the material events and caused by material structures and social events are caused by social structures.

CHAPTER 2. LITERATURE REVIEW

This chapter reviews the extant literature on *features*, *ability* and *affordances* in order to explore their underlying constitutive elements (Chemero, 2003; Şahin et al., 2007; Stoffregen, 2003). Each review of the respective *feature*, *ability* and *affordance* construct is followed by the relevant propositions for further exploration.

2.1 Introduction

“Standing on the shoulders of giants…” is a metaphor commonly used when referring to literature reviews (Vom Brocke et al., 2015). This is because, depending on the goal (i.e. phenomena *explaining*, *describing*, *understanding*, and/or *theory testing*), literature reviews can immensely contribute the research endeavour (Rowe, 2014; Schryen et al., 2020). Such contributions can *inter alia* include: (a) synthesizing knowledge relevant to the study; (b) aggregating theoretical evidence; criticizing extant theories; (c) developing and/or proposing theory; (d) identifying knowledge or research gaps; and (e) suggesting research agenda (Schryen et al., 2020).

The current review is a *narrative review* (Juntunen & Lehenkari, 2019; Paré et al., 2015). The review seeks to *synthesise* relevant propositions (Schryen et al., 2020), by *describing* and *explaining* extant knowledge relevant to the study (Rowe, 2014). The purpose of the review is to analyse and synthesise relevant theoretical context of *digital technology affordances* (Autio et al., 2018; Nambisan et al., 2017; Yassaee & Winter, 2017). The review will be concluded by synthesising relevant propositions towards exploring the context of the causal mechanisms (Markus & Robey, 1988; Markus & Rowe, 2018) of digital technology affordances (Markus & Silver, 2008) as well as their formalisms (Andries et al., 2018; Chemero, 2003).

2.2 Definition of topic or background discussion

Studies regarding the use of technology by social actors need to consider the context of their situated *social use* setting (Cheikh-Ammar, 2018; Orlikowski & Iacono, 2001; Silver & Markus, 2013) including their *lifeworld* or *real-world* lived experiences (Basden, 2009; Beeson, 2001; Wang et al., 2016). Thus the *use* of technological

artefacts in social settings should appropriately be explained through *sociomateriality* (Faraj & Azad, 2012; Leonardi, 2013a; Orlikowski, 2007; Thambusamy & Nemati, 2011).

Sociomateriality in the context of digital technologies is such that technology through its *features* or functions and other characteristics, affords social actors' various opportunities for action — *affordances* (Cabiddu et al., 2014; Faraj & Azad, 2012; Van Osch & Mendelson, 2011). Users interact with digital technologies by acting upon the action possibilities afforded by the technology *features* (Cabiddu et al., 2014; Costa, 2018; Leidner et al., 2018; Leppänen et al., 2015). These *action possibilities* are as a result of *imbrications* (i.e. both *material→social* and/or *social→material*) (Leonardi, 2011) of the *social* and *material* (i.e. technology) agencies (Cabiddu et al., 2014; Leidner et al., 2018).

These sociomaterial action possibilities are also referred to as "**affordances**" (Cabiddu et al., 2014; Faraj & Azad, 2012; Van Osch & Mendelson, 2011). Affordances as social constructs are a useful way of considering the sociomateriality of technology in the social context (Fayard & Weeks, 2014). In the context of sociomateriality, it is not sufficient to only consider what features technology provides, but also whether the social actors can perceive and leverage such features (Anderson & Robey, 2017). Thus, affordances are a way of contextually conceptualising the action possibilities that technology "affords" to social actors (Fayard & Weeks, 2014; Pozzi et al., 2014).

Affordances are by definition contingencies (Chemero, 2003). Affordances are "relations between the *abilities* of organisms and *features* of the environment" (Chemero, 2003, p. 189). Furthermore, affordances are contingent upon the situational context (Turner, 2005) — the environmental features and abilities or contextual behaviours of social actors (Chemero, 2003; Fayard & Weeks, 2014; Withagen et al., 2012). Affordances are thus emergent *action possibilities* resulting from *material→social* and/or *social→material imbrications* (Leonardi, 2011). The realisations of actions from those *material-social* action possibilities are what is meant by affordance actualisation.

2.3 What is ability?

The *Stanford Encyclopedia of Philosophy* outlines a survey of various conceptions of *ability* ranging from *disposition*, *power*, '*know-how'* and/or *restricted possibility* (Maier, 2018). Ability is to be able to do something or to appropriately and/or effectively execute actions based on set rules (Zahle, 2017). Ability is practical knowledge or experiential know-how (Alter, 2001; Cath, 2009). To define *ability* as a construct and not as an attribute of human capacity, the parametric aspects of *descriptive psychology* (DP) will be explored (Bergner, 2010, pp. 325–355, 2011).

2.3.1 *Ability logic*

As previously noted, 'ability' is practical knowledge or experiential know-how (Alter, 2001; Cath, 2009). Ability is the demonstrated know of doing something or appropriately and/or effectively executing actions based on set rules (Zahle, 2017). Ability involves discriminatory *knowledge* of something (Alter, 2001; Cath, 2009; Lum, 2017; Pavese, 2017). Ability as knowledge is *preconditional, propositional*, *procedural*, and *goal-oriented* know-how (Lau & Wang, 2016; Y. Wang, 2018). This form of know-how can be expressed through the $\boldsymbol{Kh}_{\mathbf{S}}(\psi, \boldsymbol{P}, \Phi)$ modal expression, where $\boldsymbol{Kh}_{\mathbf{S}}$ is the modal know-how operator for the social agency or subject ***S***, under the state of affairs or *precondition* proposition ψ, *method* predicate ***P***, and *goal* proposition Φ (Lau & Wang, 2016; Y. Wang, 2018). The logic of the $\boldsymbol{Kh}_{\mathbf{S}}(\psi, \boldsymbol{P}, \Phi)$ modal expression is to be read as follows:

> "***S*** *knows how to achieve* Φ *by method* ***P*** *under precondition* ψ" … "is true if and only if, there is a way ω, and it is a way of the method ***P***, and ***S*** can guarantee Φ by ω under precondition ψ; ***S*** knows that ω is a way of the method ***P***, and ***S*** knows that ***S*** can guarantee Φ by ω under precondition ψ" (Lau & Wang, 2016, p. 418).

According to Wang (2018) where $\boldsymbol{Kh}(\psi, \boldsymbol{P}, \Phi)$ holds in one model it can also be proven to hold in another model (2018, p. 4436). Thus, it is possible that the $\boldsymbol{Kh}(\psi, \boldsymbol{P}, \Phi)$ logic can, also hold in another *propositional*, *procedural*, and *preconditional* models (Lau & Wang, 2016; Y. Wang, 2018).

2.3.2 *Social behaviour*

Descriptive Psychology (DP) is a four-concept *framework* (i.e. *conceptual framework*) — *Person, Behaviour, Language, and Reality* used to conceptualise social phenomena (Bergner, 2010, pp. 326, 333). *DP* employs a parametric analysis to formally describe social phenomena (Bergner, 2010, pp. 325–355). For instance, social *behaviour* (Bergner, 2011, 2016); *legal culpability* (Littmann, 2010, pp. 87–109); *empathy* (Schwartz, 2013, pp. 203–217); and many other aspects of social phenomena (Putman, 2010, pp. 9–38), have been studied using DP parametric analysis. For this study, only the *behaviour* concept as an expression of *ability* is deemed relevant.

Human behaviour as intentional action <**IA**> can be conceptualised as a parametric formulation of eight parameters — *Identity* <**I**>; *Want* <**W**>; *Know* <**K**>; *Know-How* <**KH**>; *Performance* <**P**>; *Achievement* <**A**>; *Personal Characteristic* <**PC**>; and *Significance* <**S**>, expressed as a parametric set notation formulation (see formula [Bh1]) (Bergner, 2010, pp. 334–341, 2011, 2016; Ossorio, 2013, pp. 44–68):

Behaviour = <**IA**> = < **I**, **W**, **K**, **KH**, **P**, **A**, **PC**, **S** > [Bh1]

2.3.3 *Ability description*

The DP conceptual framework also employs a *calculational system* to describe behavioural phenomena (Ossorio, 2013, pp. 39–42, 55–68). The calculational system can be used to instantiate various behavioural descriptions (intentional action <**IA**> or behaviour <**B**> descriptions) (Table 1) using three operations — *substitution*, *deletion*, and *identity* (Ossorio, 2013, p. 55).

The appropriate and basic intentional action <IA> specification for human agency in the real world is the *agency description* <θ, **W**, **K**, **KH**, **P**, **A**, θ, θ> (Ossorio, 2013, p. 63). The *agency description* represents an “instrumental, purposive, or goal-oriented phenomenon,” and can be used to describe the (a) the individual person characteristics or the *person* concept; (b) the historical context and social patterns of behaviour (i.e. *social practice*); and can be recursively instantiated into other behaviours (Ossorio, 2013, p. 63).

Table 1 Behaviour instantiations (adapted Ossorio, 2013, pp. 56–78)

Operation	Product	Description
Substitution	< **I**, **W**, <**B**>, **KH**, **P**, **A**, **PC**, **S** >	Cognizant Action formula
Substitution	< **I**, <**B**>, <**B**>, **KH**, **P**, **A**, **PC**, **S** >	Deliberate Action formula
Substitution	< **I**, **W**, **K**, **KH**, **P**, <**B**>, **PC**, **S** >	Social Practice formula
Substitution	< **I**, **W**, **K**, **KH**, <**B**>, **A**, **PC**, **S** >	Symbolic Behaviour formula
Deletion	< θ, **W**, **K**, **KH**, **P**, **A**, θ, θ >	***Agency/Ability Description***
Deletion	< θ, **W**, OBJ, **KH**, **P**, **A**, θ, θ >	Attitude Description
Deletion	< θ, θ, **K**, **KH**, **P**, **A**, θ, θ >	***Activity Description***
Deletion	< θ, **W**, **K**, **KH**, **P**, θ, θ, θ >	***Attempt Description***
Deletion	< θ, θ, θ, θ, **P**, **A**, θ, θ >	Performance Description
Deletion	< θ, **W**, θ, θ, θ, θ, θ, θ >	Values Description
Deletion	< θ, θ, θ, θ, θ, **A**, θ, θ >	Achievement
Deletion	< θ, θ, **K**, θ, θ, θ, θ, θ >	Knowledge Description
Deletion	< θ, θ, OBJ, θ, θ, θ, θ, θ >	Interest Description
Deletion	< θ, θ, θ, θ, **P**, θ, θ, θ >	Style Description
Deletion	< θ, θ, **K**, θ, **P**, θ, θ, θ >	Stimulus-Response Description
Deletion	< θ, θ, **K**, θ, θ, **A**, θ, θ >	Stimulus-Response Description
Deletion	< θ, θ, **K**, θ, **P**, **A**, θ, θ >	Stimulus-Response Description

For instance, according to Ossorio (2010) when human agents behave in a particular way in the real world, they are effectively making distinctions on those particular concepts in the real world (2010, pp. 45–54). These concepts in the real world are described by the *real-world state of affairs* or general *knowledge* (<K> parameter) (2010, pp. 45–54). There has to be an *intent* or *goal* (<W> parameter) to perform some act (<P> parameter) to accomplish (<A> parameter) the behaviour (2010, pp. 45–54). The intent may be influenced by one or more *hedonic*, *prudential*, *ethical*, or *aesthetic* reasons (Ossorio, 2013, pp. 226–228).

The *agency description* <θ, **W**, **K**, **KH**, **P**, **A**, θ, θ> is commonly represented with the "Diamond Notation" (see Figure 3) (Ossorio, 2013, pp. 315–316). The behaviour itself is part of the heterogeneous collection of the *social practice* collective of other behaving human agencies (see Figure 3) (Ossorio, 2013, pp. 315–316). By social practice, it is implied the "heterogeneous sequence of behaviours" or "social patterns of behaviour," involving other people in context (2013, p. 169).

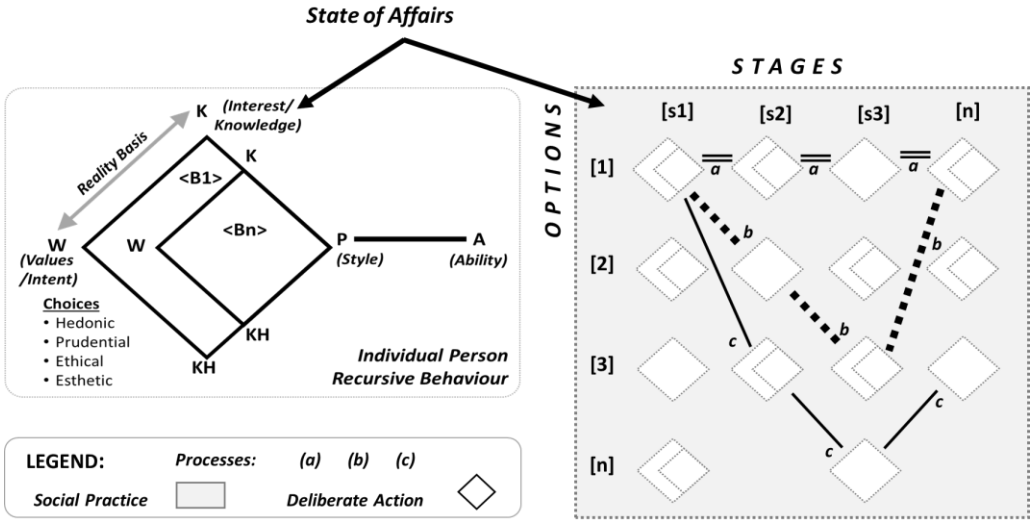


Figure 3 Agency social practice

(adapted Ossorio, 2013, pp. 315–316)

In the diagram above (see Figure 3), human behaviour in the context of *social practice* is outlined. The "white diamonds" reflect the possible individual behaviours as *agency descriptions* within the *social practice* system (i.e. grey rectangle). The social practice system delineates two dimensions — *options* dimension, and the *stages dimension*. The *stages* dimension describes the logical sequence of behaviours that behaving individuals can perform in the real world, whilst the *options* are the number of possible ways of behaving in the real world (Ossorio, 2013, pp. 315–316). Furthermore, the social practice as a logical historical sequence of individual behaviours can also be described as a process in the state of affairs system (Ossorio, 2013, pp. 219–220).

The *agency description* also specifies ability as a human trait (Ossorio, 2013, pp. 63, 71–72). Thus like all other human traits, 'ability' is therefore described as five-parameter agency description: <θ, **K**, **W**, **KH**, **P**, **A**, θ, θ> (Ossorio, 2010, pp. 33–43, 53). For ease of reference and disambiguation, the *ability* parameters are hereafter suffixed with an '*S suffix'* for '*social ability'* (i.e. $\boldsymbol{KH_S}$ for social know-how or knowledge; $\boldsymbol{A_S}$ for social achievement; $\boldsymbol{W_S}$ for social *motivation*, *intention* or *goal*; $\boldsymbol{P_S}$ social for *procedural dexterity*; $\boldsymbol{K_S}$ for social *preconditions* or *state of affairs*). This implies that, given the *state of affairs* $\boldsymbol{K_S}$, and *intention* $\boldsymbol{W_S}$, '*ability'* is having the *know-how* $\boldsymbol{KH_S}$, and *procedural dexterity* $\boldsymbol{P_S}$, to reach the goal achievement $\boldsymbol{A_S}$, as follows (see formula [Bh2] and Table 1):

Ability = (***W*****S**, ***K*****S**, ***KH*****S**, ***P*****S**, ***A*****S**) [Bh2]

However, given the *state of affairs* ***K*****S**, and NO *intention* (***W*****S**:=*θ*), the *know-how* ***KH*****S**, and *procedural dexterity* ***P*****S**, to reach an *unintended* achievement ***A*****S**, the performance would be a mere activity similar to an *ad-libbed fluke* action or '*winged fluke* action' — *Activity Description* (see formula [Bh3] and Table) (Ossorio, 2013, pp. 63–64):

Activity = (***K*****S**, ***KH*****S**, ***P*****S**, ***A*****S**) [Bh3]

Likewise, given the *state of affairs* ***K*****S**, the *intention* ***W*****S**, the *know-how* ***KH*****S**, and *procedural dexterity* ***P*****S**, that does NOT *accomplish* anything (***A*****S**:=*θ*), the performance is an attempt and not, 'ability' — *Attempt Description* (see formula [Bh4] and Table) (Ossorio, 2013, pp. 64–65):

Attempt = (***W*****S**, ***K*****S**, ***KH*****S**, ***P*****S**) [Bh4]

Since ability is practical knowledge or experiential know-how (Alter, 2001; Cath, 2009). Ability is thus experiential *know-how* ***KH*****S** knowledge to accomplish an *achievement* ***A*****S** by artefact usage *procedural dexterity* ***P*****S** motivated by *goal* ***W*****S** under the specified *state of affairs* ***K*****S** (Alter, 2001; Cath, 2009; Ossorio, 2010, pp. 33–43, 53). Put differently, 'ability' is to be able to do something (i.e. *achievement* ***A*****S**) or to appropriately and/or effectively execute actions (i.e. *procedural dexterity* ***P*****S**) based on set rules (i.e. *know-how* ***KH*****S** knowledge) (Zahle, 2017).

Furthermore, as noted previously, ability as knowledge can be expressed through the ***Kh***(ψ,***P***, Φ) modal expression having *precondition* ψ, *proposition* ω, *procedure* ***P***, and *goal* Φ (Lau & Wang, 2016; Y. Wang, 2018). It is worth noting that the ability specification: *(W, K, KH, P, A)*, also involves goal <W> (propositional and/or goal-oriented), state of affairs <K> (preconditions), procedural dexterity or performance <P> (procedural), and achievement <A> (goal-oriented) (Ossorio, 2010, pp. 33–43, 53).

Thus it seems reasonable therefore that ability specification: (***W*****S**, ***K*****S**, ***KH*****S**, ***P*****S**, ***A*****S**) (Ossorio, 2010, pp. 33–43, 53) could also be expressed through the know-how modal expression: ***Kh***(ψ,***P***, Φ) (Lau & Wang, 2016; Y. Wang, 2018), where *goal* Φ refers to social goal ***W*****S**; precondition ψ refers to the *state of affairs* ***K*****S**; the know-how of

subject ***S*** refers to social know-how ***KHs***; method ***P*** refers to social procedural dexterity ***Ps*** or performance, and the *way of goal achievement* ω refers to social achievement ***As***, and read as follows:

> ***S*** *knows how* ***KHs*** *to achieve* ***Ws*** *by method* ***Ps*** *under precondition* ***Ks***; is true if and only if, there is a way ***As***, and it is a way of the method ***Ps***, and ***S*** can guarantee ***Ws*** by ***As*** under precondition ***Ks***; ***S*** knows that ***As*** is a way of the method ***Ps***; and ***S*** knows that ***S*** can guarantee ***Ws*** by ***As*** under precondition ***Ks*** (Lau & Wang, 2016, p. 418).

2.3.4 *Proposition 1: Ability structural elements*

RQ1: What are the underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances*? The plausible underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances* are *know-how* ***KHs*** knowledge to accomplish an *achievement* ***As*** by *procedural dexterity* ***Ps*** of using an artefact, motivated by *goal* ***Ws*** under the specified *state of affairs* ***Ks*** (Alter, 2001; Cath, 2009; Ossorio, 2010, pp. 33–43, 53). The underlying structural elements as proposed by Ossorio (2010) can be formalised as a five-parameter construct: (***Ws, Ks, KHs, Ps, As***), as follows (see formula [Bh2]):

Ability = (***Ws, Ks, KHs, Ps, As***) [Bh2]

Ability is also to be able to do something (i.e. *achievement* ***As***) or to appropriately and/or effectively execute actions (i.e. *procedural dexterity* ***Ps***) based on set rules (i.e. *know-how* ***KHs*** knowledge) (Zahle, 2017).

2.4 What are features?

Affordances are relational constructs between *features* of the environment and the *abilities* of the subject (Chemero, 2003). This section explores the *feature* aspects of affordances.

2.4.1 *Features overview*

A feature is "an entity intentionally introduced in the physical product or its model, thus made (created) or described (selected) on purpose to satisfy certain requirements" (Sanfilippo & Borgo, 2016, p. 15). Features are aspects of artefacts and cannot exist by themselves (i.e. they are always related to artefacts) (Sanfilippo & Borgo, 2016). A feature can be defined as a set of *specifications* conforming to specified properties within a domain, to meet a set of related *requirements* (Classen et al., 2008, p. 21). Defined formally, ***feature f*** (see formula [Ff1]), is a tuple where, feature *specification* ***S***, set of related feature *requirements* ***R***, feature domain *properties* or *assumptions* **W**, are its elements (Classen et al., 2008, p. 21):

$$feature = (R, W, S) \quad [Ff1]$$

At an ontological level, there are two broad categories of features: *physical features* (*p-features*) and *informational features* (*i-features*) (Sanfilippo & Borgo, 2016). *P-features* are physical entities in time and space, whose properties, form and functions are specified by one or more *i-features* (Sanfilippo & Borgo, 2016). Thus depending on their base ontological level (i.e. *i-feature* or *p-feature*), features can be further classified *inter alia* into the following types: *component; form; geometric; machining;* or *material features* (Sanfilippo & Borgo, 2016); *kinematic; unified; associative;* or *manufacturing features* (Cheng & Ma, 2017a); *assembly*, or *functional features* (Cheng & Ma, 2017a; Sanfilippo & Borgo, 2016). The focus of this study is on technology *functional features*.

2.4.2 *Feature affordances*

Technology features, in general, are component building blocks of technology (Griffith, 1999) or structural/functional properties of technology (Cheikh-Ammar, 2018). Technology features are also its *functional* properties (Asnina, 2013; Osis et al., 2008, 2007; Osis & Asnina, 2011; Osis & Donins, 2017) or actionable characteristics (rules) and resources for action (DeSanctis & Poole, 1994).

Users interact with technology in social use situations through the affordances that the technology affords such users (Bernhard et al., 2013; Evans et al., 2017; Markus & Silver, 2008). That is, given the available technology *features*, and corresponding abilities of users, the *afforded* behaviour of the social actor(s) will be a relational function between the *features* (material) and the extent of the user's *abilities* (social) to perceive and use such features (Chemero, 2003). However, not all features may be available for use by technology users at any point in time (Sun, 2012). Features may be unavailable for use due to being unfamiliar or unknown or simply unusable or unactable features (Sun, 2012).

Features in use are a subset of the overall technology features; they are — "the basket of system features that are ready to be used by a particular user to accomplish tasks" (Sun, 2012, p. 455). *Features in use* that provide affordances are referred to as *affordance features* (Lim & Kim, 2009). *Affordance features* can be *functional* (operational effectivity) *ergonomic* (operational convenience), and *informative* (operational guidance) (Lim & Kim, 2009). Features not in the user's *features in use* basket (Sun, 2012), will likewise not provide affordances, and thus cannot be *affordance features* (Lim & Kim, 2009).

In the context of digital technologies, these a*ffordance features* (Lim & Kim, 2009) can be *programmable* (has modifiable logic and functions) (Yoo, 2010). They can also be *addressable* (distinguishable from other similar artefacts); *senseable* (able to sense and be sensed); *communicable* (able to communicate with other artefacts); *memorizeable* (record and store generated, sensed, and/or communicated information); *traceable* (able to trace back its activities); and *associable* (relatable to other entities) (Yoo, 2010). They can also be configured or arranged in various technology configurations such as, *platform, connectivity, actor-based product,*

sensor-based data collection, analytical insight generation, analytical interaction, and *augmented interaction* type of technologies (Berger et al., 2018). The architecture of these digital technology configurations typically consist of layers: *device*, *network*, *content*, and *service* layers (Berger et al., 2018; Yoo et al., 2010).

2.4.3 *Functional features*

Functional features specify the *functions* or the functionality of artefacts (Cheng & Ma, 2017a). A *function* is an inclusive, *design intent* or *purpose*, *processual transformations* (i.e. information, energy and/or material transformations), and artefact *behaviour* triplet (Cheng & Ma, 2017a). The *function* triplet — *purpose*, *transformation*, and *behaviour*) corresponds, albeit indirectly to the feature triplet (f = (R, W, S) see formula [6]) definition. That is, the design intent corresponds to the *requirements R*, *behaviour* corresponds to the *specification S*, and the *transformations* indirectly corresponds to domain context, properties and assumptions.

Functional features specify the *functions* (functional requirements), *geometric form* or *structure*, as well as the *behavioural* aspects (behavioural physics) of the artefacts (Cheng & Ma, 2017a, 2017b; Li et al., 2020). As such *functional features* are an assemblage of various feature types (i.e. geometric or form or structure, functional, behavioural, etc.) (Cheng & Ma, 2017a, 2017b; Li et al., 2020). Simply put, a *functional feature* is an inclusive *form*, *function*, and *behaviour* triplet or (*form*, *function*, *behaviour*) (Cheng & Ma, 2017a). The *form* relates to *structure*; *function* to *processual* aspects; and *behaviour* to performance aspects of artefacts (Cheng & Ma, 2017a). The *form*, *function*, and *behaviour* are respectively represented through *geometric* models, *functional decomposition* models, and *mathematical models* in functional feature representations (Cheng & Ma, 2017a).

An example *mathematical model* representation of *functional feature* is the *topological functioning model* (TFM) (Asnina, 2013; Osis et al., 2008, 2007; Osis & Asnina, 2011; Osis & Donins, 2017). *Functional features* can formally be defined (see formula [Ff2]) as a unique tuple ($\boldsymbol{A_F}$, $\boldsymbol{R_F}$, $\boldsymbol{O_F}$, $\boldsymbol{Pr_F}$, $\boldsymbol{Ex_F}$), where 'feature' is essentially a component technology entity $\boldsymbol{Ex_F}$ that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving or using action linked *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016). However, considering that such an entity $\boldsymbol{Ex_F}$, is not

just any entity, but an entity that is a component building block of technology (Griffith, 1999), *functional features* can formally be defined (see formula [Ff2]) as follows (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016):

feature = (***A$_F$, R$_F$, O$_F$, Pr$_F$, Ex$_F$***), [Ff2]

where *entity* ***Ex$_F$*** is technology component that can achieve *results* ***R$_F$***, by executing an *action* ***A$_F$***, involving or using action linked *object* ***O$_F$***, under *preconditions* ***Pr$_F$*** (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

2.4.4 *Proposition 2: Feature structural elements*

RQ2: What are the underlying structural elements and causal mechanisms of the '***feature***' construct in the emergence of *affordances*? The plausible underlying structural elements and causal mechanisms of the '***feature***' construct in the emergence of *affordances* are: technology component entity ***Ex$_F$*** that can achieve *results* ***R$_F$***, by executing an *action* ***A$_F$***, involving or using action linked *object* ***O$_F$***, under *preconditions* ***Pr$_F$,*** and formalised as follows (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

feature = (***A$_F$, R$_F$, O$_F$, Pr$_F$, Ex$_F$***), [Ff2]

where *entity* ***Ex$_F$*** is technology component that can achieve *results* ***R$_F$***, by executing an *action* ***A$_F$***, involving or using action linked *object* ***O$_F$***, under *preconditions* ***Pr$_F$*** (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

2.5 Affordances

Affordance(s) have been conceptualised as relational constructs of the actions (*behaviour*) of *actors (agents)*, *acting* on the *features* (*entity*) of the environment (Chemero, 2003; Şahin et al., 2007). According to Volkoff and Strong (2013) affordances are "… *the potential for behaviours associated with achieving an immediate concrete outcome and arising from the relation between an object (e.g., an IT artefact) and a goal-oriented actor or actors …*" (p. 823).

2.5.1 *Affordance continuum*

Affordances tend to follow a trajectory of perceptual usefulness (Smith & Pepping, 2010), from not being perceivable (i.e. not useful or actable), to perceived usefulness and actualised (Bernhard et al., 2013; Pozzi et al., 2014). That is, affordances follow a continuum of actualisation, from affordance *existence*, affordance *perception*, and affordance *actualisation* (Figure 4) (Bernhard et al., 2013; Nagy & Neff, 2015; Pozzi et al., 2014; Smith & Pepping, 2010; Zhao et al., 2013). Put differently affordances have *potency* (Anderson & Robey, 2017), and their potency is a function of their actualisation along the actualisation continuum (Bernhard et al., 2013; Pozzi et al., 2014).

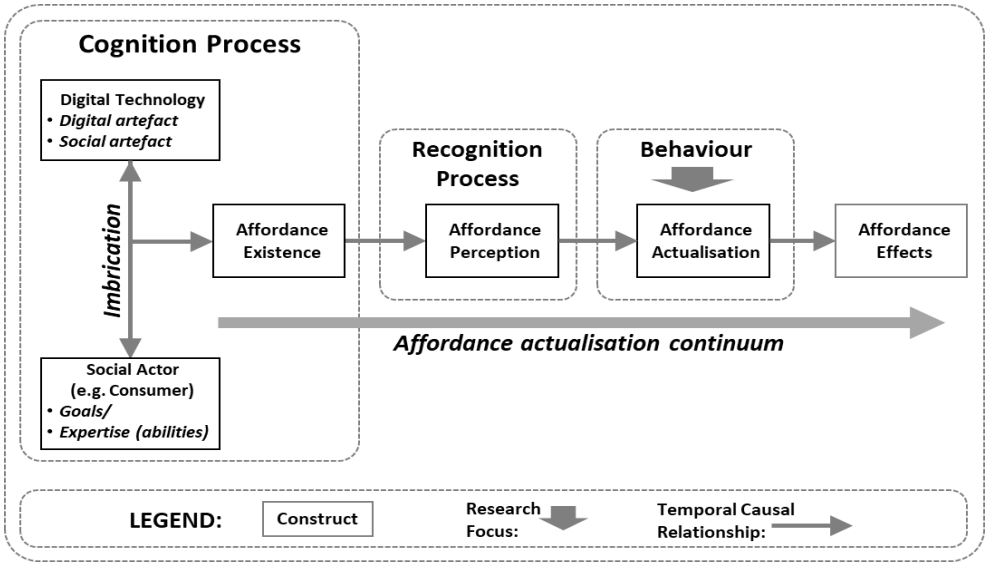


Figure 4 Affordance actualisation continuum
(adapted Pozzi et al., 2014)

As relational constructs, affordances are perceived as (a) relation between artefact class and social convention (*canonical affordance*); (b) relation between designer, artefact, and imagined users (*designed affordances*); (c) relation between artefact and actual users (*potential affordances*); and (d) relation between artefact and actual users (*outcome affordances* or affordances as completed actions) (Lanamäki et al., 2016). The realisations of actions from those *material-social* action possibilities are what is meant by affordance actualisation (Leonardi, 2011).

Affordances can also be viewed as situational use constructs or contextual constructs (Anderson & Robey, 2017; Fayard & Weeks, 2014; Turner, 2005). As such (i.e. contextual constructs), affordances are actualised through mechanisms under specified corresponding conditions (Davis & Chouinard, 2017). The affordance mechanisms are viewed as artefact *request*, *demand*, *allow*, *encourage*, *discourage*, and *refuse* mechanisms of *actualisation* (Davis & Chouinard, 2017). The mechanisms of *actualisation* are predicated upon by the user *dexterity, cultural* and *institutional legitimacy,* and *perception or* artefact *perceptiveness* conditions (Davis & Chouinard, 2017). Affordances are also viewed as artefact predispositions of social actors to afforded behaviour (Tillas et al., 2017; Withagen et al., 2012). Affordances are also perceived as *reactive*, *reflective*, and *reflexive* constructs (Kannengiesser & Gero, 2012).

Affordances are aspects of *sociomateriality* (Bloomfield et al., 2010; Fayard & Weeks, 2014; Gasson, 2012; Kautz & Jensen, 2012; Leonardi, 2011, 2012, 2013a; Orlikowski, 2007; Pentland et al., 2012; van Dijk & Rietveld, 2017; Van Osch & Mendelson, 2011; Volkoff & Strong, 2017). Affordances are a way of contextually conceptualising the action possibilities that the *material* (i.e. technology) “affords” to *social* actors (Fayard & Weeks, 2014; Pozzi et al., 2014). Affordances are relational constructs (Chemero, 2003) providing possibilities for action (Bernhard et al., 2013; Markus & Silver, 2008). Affordances are thus sociomaterial action possibilities (Cabiddu et al., 2014; Faraj & Azad, 2012; Van Osch & Mendelson, 2011). In terms of *sociomateriality*, it is not sufficient to only consider what features technology provides, but also whether the social actors can perceive and leverage such features (Anderson & Robey, 2017).

2.5.2 *Affordance formalism*

Some of the earlier contributions on the formalisation of affordances include: (a) studies in *causal relation* mechanisms (Steedman, 2002), (b) affordances as properties of the *animal–environment* system (Stoffregen, 2003), (c) outcome of environmental feature and animal ability or *feature–ability* relations (Chemero, 2003), (d) *feature-ability* relations in an *animal–environment* system (i.e. *animal–feature–ability* system) (Cakmak et al., 2007; Şahin et al., 2007); and (e) the *object–action–effect* triad in robotics (Atıl et al., 2010).

The *animal–environment* system (Stoffregen, 2003), has been used in human-environment studies to identify environmental affordances (Abbate & Bass, 2017). In the *animal–feature–ability* system, the *animal* relates to the *agents* or *actors* in the system, the *environment* to features or actable *entities*, and ability relates to behaviour (Şahin et al., 2007). Since not every *feature–ability* relation leads to affordances, the relevant *feature–ability* combinations are those that lead to the afforded-behaviour (*affords*-**ϕ**) (Chemero, 2003) or *effects* (Şahin et al., 2007). Thus, affordances are a function of the ensuant or afforded behaviour emanating from the relation between the "abilities of organisms and features of the environment" as follows: "Affords-φ (feature, ability) (p. 189) where φ is afforded behaviour or ensuant behaviour from the feature-ability relation (p. 186). Affordances, therefore, can be conceptualised as (Chemero, 2003):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

In the context of the *animal–feature–ability* system, three affordance perspectives are distinguishable: *agent*, *environment*, and *observer* perspectives (Cakmak et al., 2007; Şahin et al., 2007; Zech et al., 2017):

agent affordance = (*effect*, (*entity*, *behaviour*)) [Aff2]
environment affordance = (*effect*, (*agent*, *behaviour*)) [Aff3]
observer affordance = (*effect*, (*agent*, (*entity*, *behaviour*))) [Aff4]

The *agent affordance* perspective is agent-oriented, wherein the affordances are a function of the agent's ability and dexterity to leverage the affordances in the environment (Cakmak et al., 2007; Şahin et al., 2007). It is the agent's capacity, to perceive and affect the feature-ability relation (Chemero, 2003), or the (*entity*,

behaviour) tuple for action (Şahin et al., 2007). It provides the *'what can the agent do'* perspective. According to Cakmak et al (2007), the agent perspective is a relevant affordance construct for robotics. Furthermore, both formula [Aff1] and [Aff2] represent the agent perspective (Chemero, 2003; Şahin et al., 2007).

The *observer affordance* perspective introduces an observer view, to the *agent affordance perspective* (Cakmak et al., 2007; Şahin et al., 2007). It provides the *what should the agent be able to do* given *the features* in the environment, as observed by an independent observer, observing the *animal–feature–ability* system (Şahin et al., 2007). The *environment affordance* perspective provides a feature-oriented perspective, wherein the affordances are a function of the environment's superfluity of features to present to the agents (Cakmak et al., 2007; Şahin et al., 2007). It is the '*what is possible given the availability of the features in the environment'* or what the environment can offer (Şahin et al., 2007).

Furthermore, the *animal–feature–ability* system has also been used to formalise the conceptualisation robotic affordances (Cakmak et al., 2007; Yürüten et al., 2013), mapping it to the *object–action–effect* triad in robotic context as follows (Atıl et al., 2010):

affordance = (*object*, *action*, *effect*) [Aff5]

The *object–action–effect* is a relational three variable system, i.e. the *objects* in the environment, their *actions*, and the *effects* of their actions (Andries et al., 2018; Dag et al., 2010; Kammer et al., 2011; Lopes et al., 2007; Min et al., 2016; Moldovan et al., 2018; Montesano et al., 2008, 2009). In the context of the actors who use the *objects* in the environment, the *object–action–effect* system is expressed as follows (Andries et al., 2018):

affordance = *(actor, object, action, effect)* [Aff6]

The focus of the current study is on the affordances of digital technology to an engaged social actor in situated lifeworld settings (Basden, 2009; Beeson, 2001; Wang et al., 2016). In the context of an engaged social actor interacting with technology, the relevant affordance perspective for such interaction is the agent perspective (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

2.5.3 *Proposition 3: Affordance emergence*

RQ3: How do *affordances* emergence from the underlying structural elements and causal mechanisms of the '***feature'*** and '***ability'*** constructs? In terms of actor-artefact relations, affordances are relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013). As relational constructs, affordances can be expressed as follows (see formula [Aff1]) (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

The emergence of affordances can probably be associated with proposition [1] and proposition [2] structural elements as well as their *intra*-structural and/or *inter*-structural structural relations as follows:

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

> ***where*** *affords*-**ϕ** refers to the afforded behaviour or action and/or effect (Chemero, 2003; Şahin et al., 2007);
>
> ***where feature*** refers to technology component *entity* $\boldsymbol{Ex_F}$, that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, using or involving an *object* $\boldsymbol{O_F}$, given the *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016);
>
> ***where ability*** refers to the *know-how* $\boldsymbol{KH_S}$ knowledge of achieving an outcome or *achievement* $\boldsymbol{A_S}$ by *procedural dexterity* $\boldsymbol{P_S}$, motivated by *goal* $\boldsymbol{W_S}$, given the *state of affairs* $\boldsymbol{K_S}$ (Ossorio, 2010, pp. 33–43, 53).

2.6 Conclusion of Literature Review

The current *narrative review* (Juntunen & Lehenkari, 2019; Paré et al., 2015) set out to *synthesise* relevant propositions (Schryen et al., 2020), by *describing* and *explaining* extant knowledge that is relevant to the study (Rowe, 2014). The purpose of the *narrative* synthesis (Schryen et al., 2020), was to explore:

- (**RQ1**): the underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances*.
- (**RQ2**): the underlying structural elements and causal mechanisms of the '*feature'* construct in the emergence of *affordances*.
- (**RQ3**): the emergence of *affordances* from the underlying structural elements and causal mechanisms of the '*feature'* and '*ability'* constructs.

The *narrative* synthesis (Schryen et al., 2020), focused on Chemero's (2003) formulation of the affordance construct (see formula [Aff1]). Chemero's (2003) *features* and *ability* affordance formulation, respectively correspond to *entity* and *behaviour* constructs in the *agent* affordance *perspective* of Şahin et al., (2007).

In terms of the research question (**RQ1**), the plausible underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances* are *know-how* $\boldsymbol{KH_S}$ knowledge to accomplish an *achievement* $\boldsymbol{A_S}$ by *procedural dexterity* $\boldsymbol{P_S}$ of using an artefact, motivated by *goal* $\boldsymbol{W_S}$ under the specified *state of affairs* $\boldsymbol{K_S}$ (Alter, 2001; Cath, 2009; Ossorio, 2010, pp. 33–43, 53). The underlying structural elements as proposed by Ossorio (2010) can be formalised as a five-parameter construct: ($\boldsymbol{W_S, K_S, KH_S, P_S, A_S}$), as follows (see formula [Bh2]):

$$Ability = (\boldsymbol{W_S, K_S, KH_S, P_S, A_S}) \quad [Bh2]$$

Ability also means to be able to do something (i.e. *achievement* $\boldsymbol{A_S}$) or to appropriately and/or effectively execute actions (i.e. *procedural dexterity* $\boldsymbol{P_S}$) based on set rules (i.e. *know-how* $\boldsymbol{KH_S}$ knowledge) (Zahle, 2017).

In terms of the research question (**RQ2**), the plausible underlying structural elements and causal mechanisms of the '*feature'* construct in the emergence of *affordances* are

technology component entity ***Ex$_F$*** that can achieve *results* ***R$_F$***, by executing an *action* ***A$_F$***, involving or using action linked *object* ***O$_F$***, under *preconditions* ***Pr$_F$,*** and formalised as follows (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

feature = (***A$_F$, R$_F$, O$_F$, Pr$_F$, Ex$_F$***), [Ff2]

where *entity* ***Ex$_F$*** is technology component that can achieve *results* ***R$_F$***, by executing an *action* ***A$_F$***, involving or using action linked *object* ***O$_F$***, under *preconditions* ***Pr$_F$*** (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

Judging by the extant literature reviewed, affordances have been conceptualised in various ways (Chemero, 2003; Şahin et al., 2007). For instance, affordances are perceived as *causal relation* mechanisms (Steedman, 2002); properties of the *animal–environment* system (Stoffregen, 2003); the outcome of environmental *feature* and animal *ability* or *feature–ability* relations (Chemero, 2003); *feature-ability* relations in an *animal–environment* system (i.e. *animal–feature–ability* system) (Cakmak et al., 2007; Şahin et al., 2007). In terms of robotics studies, affordances are *object–effect–action* or *actor-object–action–effect* interactions (Andries et al., 2018; Atıl et al., 2010; Dag et al., 2010; Kammer et al., 2011; Lopes et al., 2007; Min et al., 2016; Moldovan et al., 2018; Montesano et al., 2008, 2009). In terms of *actor-artefact* relations, affordances are relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013). The types of formalisations advanced to conceptualise affordances include *inter alia*:

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]
agent affordance = (*effect*, (*entity*, *behaviour*)) [Aff2]
environment affordance = (*effect*, (*agent*, *behaviour*)) [Aff3]
observer affordance = (*effect*, (*agent*, (*entity*, *behaviour*))) [Aff4]
affordance = (*object*, *action*, *effect*) [Aff5]
affordance = *(actor, object, action, effect)* [Aff6]

In terms of the research question (**RQ3**), the emergence of affordances can probably be associated with proposition [1] and proposition [2] structural elements as well as their *intra*-structural and/or *inter*-structural relations as follows:

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

where *affords*-**ϕ** refers to the afforded behaviour or action and/or effect (Chemero, 2003; Şahin et al., 2007);

where feature refers to technology component *entity* $\boldsymbol{Ex_F}$, that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, using or involving an *object* $\boldsymbol{O_F}$, given the *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016);

where ability refers to the *know-how* $\boldsymbol{KH_S}$ knowledge of achieving an outcome or *achievement* $\boldsymbol{A_S}$ by *procedural dexterity* $\boldsymbol{P_S}$, motivated by *goal* $\boldsymbol{W_S}$ given the *state of affairs* $\boldsymbol{K_S}$ (Ossorio, 2010, pp. 33–43, 53).

CHAPTER 3. RESEARCH METHODOLOGY

In this chapter, the research method, approach, and philosophical stance underlying the research are outlined. The key focus of the study is on the nature of the *feature-ability* construct as it relates to affordances (Chemero, 2003). That is*, what aspect* of the *features*, are the *'affecting what'*, of '*what aspect'* of *behaviour*, and *in which way*.

3.1 Research approach

The current study involves exploring the conditional causal mechanisms (Davis & Chouinard, 2017) between user *abilities* and digital technology *features* (Chemero, 2003). Thus, the study seeks to explore the emergence or manifestation of affordances from the interactions of such *features* with user *abilities*.

3.1.1 *Meta-reality*

The nature of *reality* (*meta-reality*) (Hartwig, 2015, p. 304) involves the sorts of things that (circumstances permitting) can be sensed unaidedly (i.e. *observables*), and those that cannot (i.e. *unobservables*) (Chakravartty, 2007, pp. 3–26). However, among those sorts of things that cannot be sensed unaidedly (*unobservables*), there are those that can be detected (i.e. *detectables*) through various means including *inter alia* instruments, etc., and those that cannot be detected (i.e. *undetectables*), but only inferred upon (Chakravartty, 2007, pp. 3–26).

The philosophy of *meta-reality* (PMR) has undergone several developmental moments, namely: (a) *transcendental realism* (TR); (b) *critical naturalism* (CN); (c) the theory of *explanatory critiques* (EC); (d) *dialectical critical realism* (DCR); and (e) *transcendental dialectical critical realism* (TDCR) (Bhaskar, 2008a, pp. ix–xx). Each preceding moment is preservatively assimilated in the succeeding moment (Bhaskar, 2008a, pp. ix–xx). That is, each succeeding moment adds onto the preceding moment, forming an integrated philosophical system of *meta-reality* (PMR system) which can be articulated as follows (Bhaskar, 2008a, pp. ix–xx):

> PMR>TDCR>DCR>EC>CN>TR, where '>' stands for preservatively assimilates or sublates.

The PMR system can also be articulated through the MELDARA seven dimensions of being or the ontological-axiological chain as follows (Bhaskar, 2008a, pp. ix–xx):

> 7**A**>6**R**>5**A**>4**D**>3**L**>2**E**>1**M**, where *first moment* (1**M**); *second edge* (2**E**); *third level* (3**L**); *fourth dimension* (4**D**); *fifth aspect* (5**A**); *sixth realm* (6**R**); and *seventh awakening* (7**A**) are ontological dimensions and where each higher dimension preservatively contains the lower.

Among these developmental moments of PMR, *transcendental realism*; *critical naturalism*; the theory of *explanatory critiques*; and *dialectical critical realism* constitute the four basic tenets of *critical realism* (Archer et al., 1998; Bhaskar, 2008a, 2008b; Hartwig, 2015, p. 96). In terms of the MELDARA ontological-axiological chain, these basic tenets of *critical realism* are preservatively contained in the MELD dimensions as follows (Hartwig, 2015, p. 296):

> 4**D**>3**L**>2**E**>1**M**, where *first moment* (1**M**); *second edge* (2**E**); *third level* (3**L**); *fourth dimension* (4**D**) are ontological dimensions and where each higher dimension preservatively contains the lower.

Transcendental realism — the notion of existential reality of concrete structures and entities with real causal contacts in a mind-independent real-world, which is *intransitive*, *transfactual*, and *stratified*, and upon which the truth value of extant and novel theories is premised (Archer et al., 1998, pp. x–xiii; Bhaskar, 2008a, pp. x–xii; Hartwig, 2015, p. 474).

Critical naturalism — the notion of society as both an emergent relational outcome and predisposing condition of human agency as epitomised by its *transformational model* of *social activity* (TMSA) (Archer et al., 1998, pp. xiii–xvii). *Critical naturalism* is both *dialectical* (i.e. dialectical critical naturalism) — epitomised by its dialectical explanatory critique; as well as *transcendental* (i.e. transcendental realist critical naturalism), in approaching and explaining the various societal dichotomies such as *structure* and *agency*, *reasons* and *causes*, *facts* and *values*, *individualism* and *collectivism*, etc. (Archer et al., 1998, pp. xiii–xvii; Hartwig, 2015, pp. 91–96).

For theoretical explanations, *critical naturalism* employs the ***DREI*** approach — ***D***escription of features; ***R***etroduction to plausible causes; ***E***limination of alternatives;

and ***I***dentification of mechanisms (Archer et al., 1998, p. xvii). For explaining praxis or applied explanations, *critical naturalism* employs the ***RRRE*** approach — ***R***esolution of complex events into components; ***R***edescription of event components, ***R***etrodiction to plausible causes; and ***E***limination of alternative causes (Archer et al., 1998, p. xvii).

Explanatory critique — the *cognitive critique* (i.e. cognitive *explanatory critique*) and *ethical critique* (i.e. needs-based *explanatory critique*) of social ills and their causal antecedents (e.g. structure, beliefs, values, etc.), through the application of *explanatory critical reason* (i.e. a type of *ethical naturalism*) (Archer et al., 1998, pp. xvii–xix, 387; Hartwig, 2015, pp. 196–201).

Dialectical critical realism — the dialecticisation (dialectical process) of concepts such as: (a) structure, differentiation, change, emergence (roughly corresponding to *transcendental realism* or non-identity); (b) *negativity* and *absences (i.e. absenting* of *constraints* on *social ills*); (c) *totality* and *holistic causality*; and (d) transformative agency and praxis, etc. (Archer et al., 1998, pp. xix–xxiv; Hartwig, 2015, pp. 130–138).

3.1.2 *"Sceptic-reality"*

Explanations and knowledge about *existential reality* (i.e. such sorts of things *observable* and/or *unobservable in the world*) have traditionally been approached from varied and nuanced forms of *empiricism*, *idealism*, and/or *realism* (Bhaskar, 2008a; Chakravartty, 2007). The *empiricist* account of the world (*empiricism*) is sceptical of the *undetectables* thus it favours experiential accounts of knowledge based on sense-data (Hartwig, 2015, p. 169). The *idealist* account of the world (*idealism*) perceives the things in the world (whether *observable* or *unobservable*, detectable, or otherwise) as mere mental constructs and projections of their perceiving *social agents* (Hartwig, 2015, pp. 246–248). The *realist* explanations of the world (*realism*) involve reality as consisting of real things (both *observables* and *unobservables*) that are independent of the minds of their perceiving social agents (Hartwig, 2015, pp. 397–400).

Scientific realism for instance, posits that "scientific theories correctly describe the nature of a mind-independent world" (Chakravartty, 2007, p. 4), and further argues for the existence of the *observables* and most of the *unobservables* posited by scientific

theories (Hartwig, 2015, pp. 397–400). *Critical realism* on the other hand further argues that such mind-independent world is also *intransitive*, *transfactual*, and *stratified* (Hartwig, 2015, p. 400). The current study takes a realist stance and employs the *critical realist* approach in particular (Archer et al., 1998; Bhaskar, 2008a; Hartwig, 2015; Sayer, 2000).

The realist argument uses “abductive inference” or “inference to the best explanation (IBE)” supported by the “no miracles argument” to explain reality (Chakravartty, 2007, p. 5). However, the cogency of the “no miracles argument” is often contentious due to counterarguments from “underdetermination of theory choice by data or evidence (UTD)” and “pessimistic induction (PI)” (Chakravartty, 2007, p. 5). As a consequence, most realist tend to restrict their stances to selected aspects of theories, i.e. *selective scepticism* (Chakravartty, 2007, pp. 27–48).The *selective sceptic* stance has several and varied views of reality, which *inter alia* includes: *entity realism, structural realism,* and *semirealism* (Chakravartty, 2007, pp. 27–48).

Entity realism postulates the existential reality of the entities described by theories, but is sceptical about the overall theories themselves (Chakravartty, 2007, pp. 27–33). *Structural realism* postulates the existential reality of the structural relations among entities described by theories, but is sceptical about the existence of those entities described by the theories (Chakravartty, 2007, pp. 33–39). There are two versions of *structural realism* — epistemic *structural realism*, and ontic *structural realism* (Chakravartty, 2007, p. 34). Epistemic *structural realism* endorses the knowledge of structural aspects of reality but is sceptical about the *nature* of those entities that are supposedly in relation to form those structures. Ontic *structural realism* perceives structures as ontological classes *sui generis*, that are non-reducible to underlying relational entities (Chakravartty, 2007, p. 34). *Semirealism* postulates the existence of concrete structures and their causal contact to the world through their detection properties, but is sceptical of their auxiliary properties (Chakravartty, 2007, pp. 39–48).

3.1.3 *Critical realism*

Critical realism advocates that causal explanations to phenomena can be inferred upon by identifying interactional mechanisms among the underlying structural *entities*

in context (Bygstad et al., 2016; Easton, 2010; Mingers, 2004; Mingers et al., 2013; Mingers & Standing, 2017; Tsang, 2014; Volkoff & Strong, 2013; Wynn & Williams, 2012; Zachariadis et al., 2013). Thus, affordances can be compared to generative mechanisms in the critical realist paradigm (Volkoff & Strong, 2013). The difference, however, is that affordances involve goal-driven agency whilst generative mechanisms do not (Volkoff & Strong, 2013). Thus, it is proposed that the critical realist approach be followed for this study (Bygstad et al., 2016; Leonardi, 2013a; Volkoff & Strong, 2013).

At the core of the critical realist ontology (i.e. the nature of being) and in accordance with the *transcendental realist* stance (Archer et al., 1998, pp. x–xiii; Bhaskar, 2008a, pp. x–xii; Hartwig, 2015, p. 474), reality exists in three domains of stratified nested existence — the *real*, *actual*, and *empirical* domains (Sayer, 2000; Dannermark et al., 2002; Easton, 2010; Mingers et al., 2013; Wynn & Williams, 2012). That is, reality, is organised in a stratified causal hierarchy among these three domains (i.e. *real*, *actual*, and *empirical* domains) (Bhaskar, 2008a; Sayer, 2000; Dannermark et al., 2002; Easton, 2010; Tsang, 2014; Wynn & Williams, 2012).

The domain of the *empirical* is a subset of the *actual*, and the *actual* is, in turn, a subset of the *real* domain (Bhaskar, 2008a; Sayer, 2000; Dannermark et al., 2002; Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Volkoff & Strong, 2013; Wynn & Williams, 2012). The domain of the *real* consist of existential *structures*, *entities* and/or generative causal *mechanisms* in reality, whose interactions lead to actual *events* in the *actual* domain, that may or may not observable as empirical *events* in the *empirical* domain (Mingers & Standing, 2017; Sorrell, 2018; Volkoff & Strong, 2013; Wynn & Williams, 2012). Mechanisms are *causal powers* or *tendencies*, whilst *events*, are specific occurrences of interest, caused by mechanism(s) (Easton, 2010; Tsang, 2014; Wynn & Williams, 2012).

The implications thereof are that; (a) reality exist independent of empirical observation (independent existence of reality); (b) reality is comprised of events, and experiences that are caused by causal mechanisms of entities and structures in the *real* domain of stratified reality; (c) observed reality is an outcome of stratified emergence (i.e. hierarchical bottom-up causation), albeit not necessarily reducible hierarchically (Bhaskar, 2008a; Sayer, 2000; Dannermark et al., 2002; Wynn & Williams, 2012).

3.1.4 *Causal reality*

In critical realism, entities (viz. *entity realism*) are things (i.e. organisations, people, artefacts, relationships, language, attitudes, resources, ideas, etc.), with event enabling causal powers and liabilities or mechanisms (viz. *semirealism*) (Chakravartty, 2007; Easton, 2010). That is, entities may be structures themselves (viz. *ontic structural realism*) or may be related to one another in structural formations through necessary relations (viz. *epistemic structural realism*) (Chakravartty, 2007; Easton, 2010).

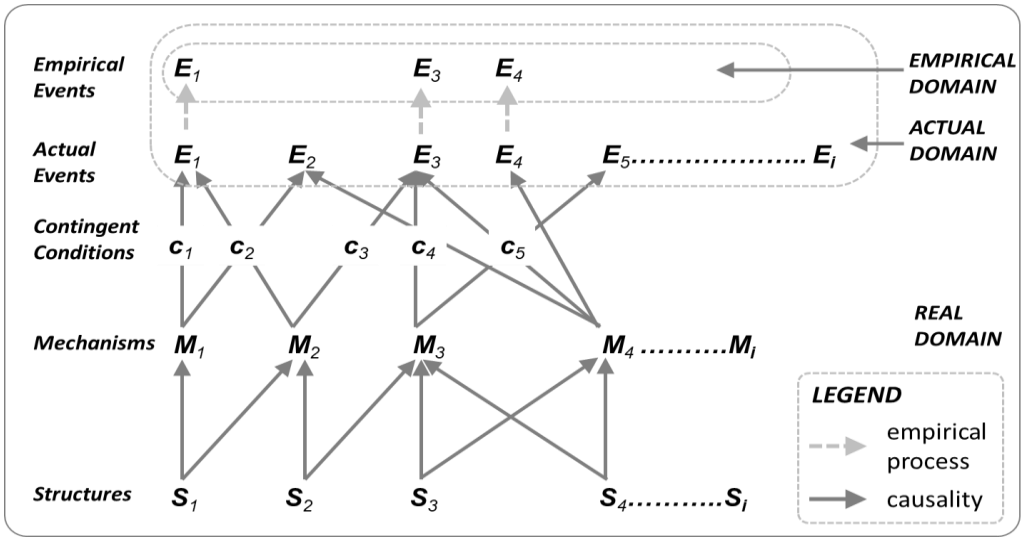


Figure 5 Outline of critical realist ontology
(adapted Sayer, 2010, p. 79; Tsang, 2014)

Relations among entities can be necessary (*substantial*) or contingent (*formal*) (Dannermark et al., 2002; Easton, 2010). The enduring nature of structure or their invariants is due to the necessary relations among its constituent entities (Dannermark et al., 2002; Easton, 2010). The activation of entity causal powers is conditional upon the entity configurations and relations both necessary and contingent (see Figure 5) (Dannermark et al., 2002; Easton, 2010; Tsang, 2014). Such conditions, (i.e. causal power activation conditions), can be intrinsic or extrinsic (Dannermark et al., 2002; Tsang, 2014). Intrinsic conditions are those built-in or inherent causal power enabling conditions (i.e. internal mechanism conditions), whereas the extrinsic conditions are external mechanisms (Tsang, 2014). Causal explanations need to account for the

entities, their mechanisms, and the events they cause to occur (see Figure 6) (Dannermark et al., 2002; Easton, 2010; Sayer, 2010, p. 74).

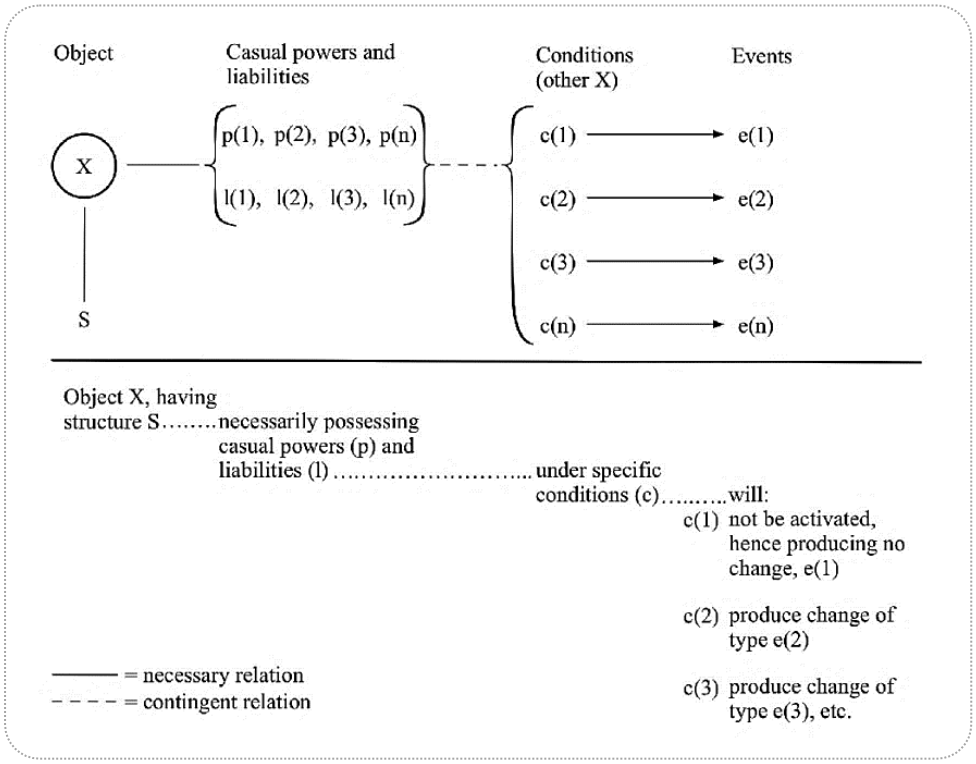


Figure 6 Typical causal explanation structure

(Sayer, 2010, p. 74)

An example of a causal explanation involving a simple case of a salesperson can be formulated as follows:

> *"Objects (a salesperson) having structures (knowledge and personality traits etc) and necessarily possessing causal powers (to persuade a buyer, who is another object) and liabilities (to be rejected by technical buyers, to get tired towards the end of the day) will, under specific condition **c1** (the buyer has a need for the product and the offering is suitable) result in an event **e1** (a sale), or alternatively under specific condition **c2** (the buyer has a need for the product but the offering is not suitable) will result in an event **e2** (no sale)*" (Easton, 2010, p. 122).

Affordances, therefore, are types of generative mechanisms in the logical sense of critical realism (Bygstad et al., 2016; Volkoff & Strong, 2013). Thus, affordances are a subset of generative mechanisms in the real domain (Volkoff & Strong, 2013). This

implies that affordances as action possibilities are located within the real domain (Volkoff & Strong, 2013). Furthermore, affordances are the ever-present action potential that may be realised as events in the actual and/or empirical domain through goal-oriented actions (Volkoff & Strong, 2013). Thus, they can also be used as proxies in the discovery of generative mechanisms in the real domain (Bygstad et al., 2016).

3.2 Research design

The critical realist research approach is primarily an explanatory research through a retroductive theoretical process (Raduescu & Vessey, 2009; Wynn & Williams, 2012; Bygstad et al., 2016). The study involves a *critical realist case study* (Caldeira, 2016; Carlsson, 2009; Easton, 2010; Tsang, 2014). The case study involves the use of a smartphone digital device by a social actor in ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016).

3.2.1 *Research type*

In terms of the critical realist stratified conception of reality, enquiries can be conducted at different layers of abstraction, dimensions, and contexts (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013). As outlined previously the domain of the *empirical* is the domain of the *observed* reality (Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Volkoff & Strong, 2013; Wynn & Williams, 2012). However, such observed reality is always contingent, and subject to revision, as novel empirical accounts are posited (Wynn & Williams, 2012). Thus, critical realism advocates that explanations of phenomena need to take into consideration the stratified nature of reality, as well as their causal inferences (Wynn & Williams, 2012).

As a consequence, the critical realist research can be classified into four types of enquiries (see Figure 7): (a) *generalisation* or extensive research; (b) *concrete* or intensive research; (c) *abstract* research; (d) *synthesis* research (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013). *Abstract* research mainly theoretical and deals with exploring and positing plausible causal explanations of reality (Sayer, 2010, p. 159). *Concrete* research is a critical realist multi-strata enquiry linking the actual and observed empirical events to their plausible causal explanations posited through

abstract theoretical research (Sayer, 2010, p. 159). *Generalisation* or extensive research seeks to establish regularities and commonalities among observed phenomena in the empirical domain (Sayer, 2010, p. 159).

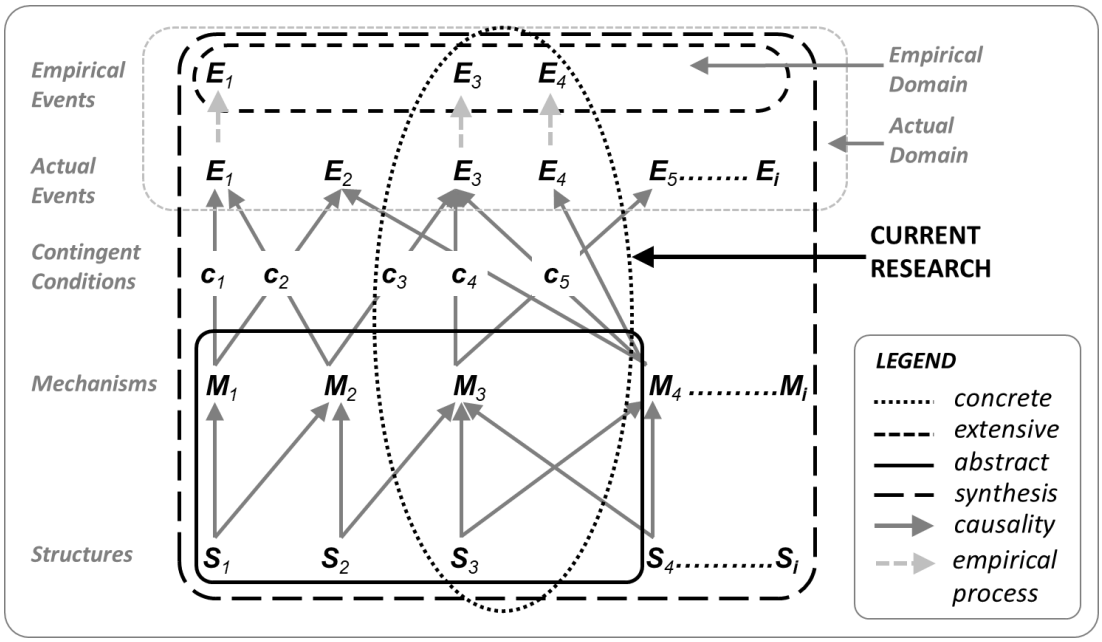


Figure 7 Critical realist research types

(adapted Sayer, 2010, pp. 79, 159)

Synthesis research is a critical realist multi-strata research integrating concrete, abstract, as well as generalization studies to explain major aspects of systemic phenomena involving various events emanating from mechanisms of various entities and structures (i.e. whole systems) (Sayer, 2010, p. 159).

The current study, therefore, is a concrete research enquiry (see Figure 7) (Sayer, 2010, p. 159; Zachariadis et al., 2013). The objective of the study is to explain the affordance phenomena by linking the observed afforded behaviour events with theoretical abstractions of their plausible causal explanations (Bygstad et al., 2016; Volkoff & Strong, 2013). Concrete research often involves few and specific cases of select events, in the form of case studies (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013). Likewise, the current study will also focus on a case study of a digital technology artefact (Goldkuhl, 2019) (i.e. Smartphone device) in lifeworld use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016).

3.2.2 *Research method*

There are three possible variants of the critical realist method: the *structured*, the *unstructured*, and the *structurable* method (Raduescu & Vessey, 2009). The choice between *structured*, *unstructured*, or *structurable* depends upon the cogency or persuasive relevance of applicable domain-specific theory (Raduescu & Vessey, 2009). In the case of strong domain-specific theory, the *structured* method is applicable, in the case of weak domain-specific theory, the *unstructured* method is applicable (Raduescu & Vessey, 2009). However, when the extant theory is indirectly related to the problem, as it is in the current study, an abductive *structurable* method is relevant (Raduescu & Vessey, 2009).

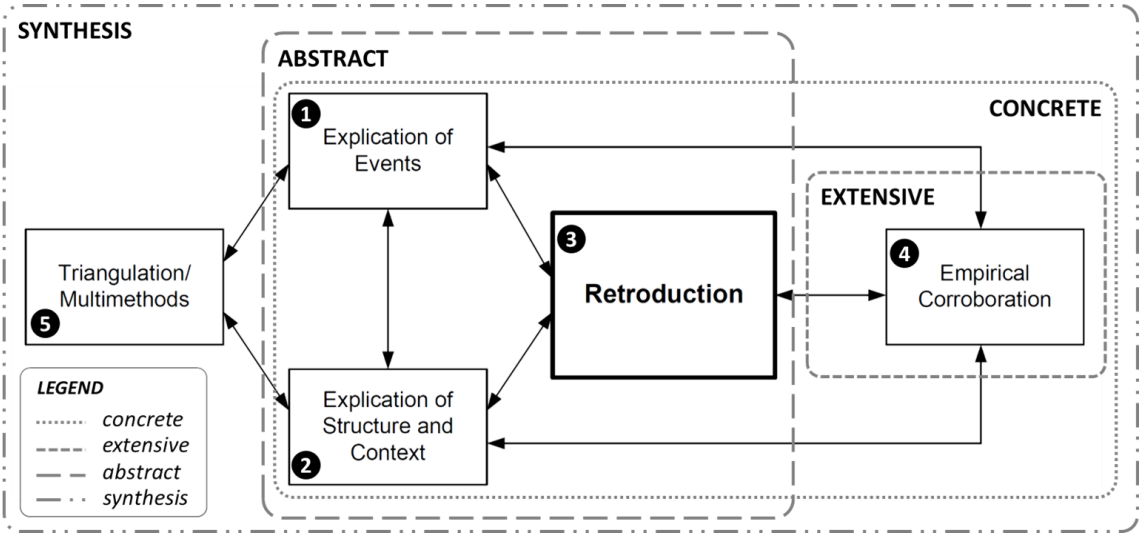


Figure 8 Critical realist research methods
(adapted Wynn & Williams, 2012)

At its core, the *structurable* method (hereafter the *critical realist* research method or *realist* method) is typically a six-step *retroductive* research process: (a) *description* (b) *analytical resolution* (c) *abduction* or theoretical *re-description* (d) *retroduction* (e) *comparison* between different theories and abstractions (f) *concretization* and conceptualization (Raduescu & Vessey, 2009). An alternate revised version of the *structurable* method specifies five retroductive research steps (see Figure 8): (i) *explication of events*; (ii) *explication of structure and context*; (iii) *retroduction*; (iv) *empirical corroboration*; and (v) *multimethod triangulation* (Wynn & Williams, 2012).

The five-step retroductive research process can be mapped to the critical realist research typology (i.e. *generalisation*, *concrete*, *abstract*, and *synthesis* research types), previously outlined as follows (see Figure 8): (a) *synthesis* (all the five steps); (b) *concrete* (all except the *multimethod triangulation* step); (c) *abstract* (all except *multimethod triangulation* and *empirical corroboration* steps); *generalisation* (involves mainly the *empirical corroboration* step) (see Table 2).

Table 2 Critical realist research method procedures

	Synthesis	**Concrete**	**Abstract**	**Generalisation**
Explication of events	**X**	**X**	**X**	**X**
Explication of structure and context	**X**	**X**	**X**	
Retroduction	**X**	**X**	**X**	
Empirical corroboration	**X**	**X**		
Multimethod triangulation	**X**			

Since the current study is intended to be a *concrete* research (see Figure 7 and Figure 8), the research process will focus on (i) *explication of events*; (ii) *explication of structure and context*; (iii) *retroduction*; and (iv) *empirical corroboration* (Wynn & Williams, 2012). The *explication of events*, *retroduction*, and *empirical corroboration* steps are crucial steps in a critical realist concrete research process and thus will be mandatory for this study (Hu, 2018). The *multimethod triangulation* step, on the other hand, is excluded in the current study and may be revisited as part of a future multi-strata wholistic synthesis research integrating concrete, abstract, and generalization studies to further explain the affordance phenomenon (Sayer, 2010, p. 159).

3.2.3 *Research procedure*

As previously noted, the current study is a critical realist *concrete* research (see Figure 7 and Figure 8), and involving the following retroductive research process steps: (i) *explication of events*; (ii) *explication of structure and context*; (iii) *retroduction*; and (iv) *empirical corroboration* (Wynn & Williams, 2012). The current study involves a case of a smartphone (i.e. digital device) in social use settings by an ordinary social actor in a

lifeworld scenario (Basden, 2009; Beeson, 2001; Wang et al., 2016). The following steps outline the procedures to be followed in the execution of the research:

a) ***Explication of events:*** the *explication of events* involves describing the observed events for which the underlying causal mechanism are to be explained (Bygstad et al., 2016; Wynn & Williams, 2012). The step "focuses on identifying a concrete event, dilemma, or situation for further analysis" (Raduescu & Vessey, 2009, p. 6).

b) ***Explication of structure and context:*** the *explication of structure and context* step is concerned with identifying and describing the key *entities*, *structures* and *interactions* involved in the observed events (Raduescu & Vessey, 2009; Wynn & Williams, 2012). In terms of the six-step, the *structurable* method noted previously, the *explication of structure and context* step (Wynn & Williams, 2012) includes the *analytical resolution* and *theoretical re-description* (Raduescu & Vessey, 2009).

   In the context of the six-step the *structurable* method, the step involves describing the situation and locating the event-causal structure in the three domains of stratified nested existence (i.e. real, actual, and empirical) (Wynn & Williams, 2012) — *analytical resolution* (Raduescu & Vessey, 2009). It also involves the *re-description* of "the components and aspects of interest, based on theories about structures and relations, as well as conceptual thinking" — *theoretical re-description* (Raduescu & Vessey, 2009, p. 6).

c) ***Retroduction:*** The *retroduction* step involves identifying and proposing the most plausible causal mechanisms to the observed phenomena or identified events (Wynn & Williams, 2012). It also involves finding alternate theories to explain the context described in the 'analytical resolution step' (Raduescu & Vessey, 2009).

d) ***Empirical corroboration:*** *empirical corroboration* (Wynn & Williams, 2012) or the c*omparison* between different theories and abstractions involves assessing the cogency of the identified or retroduced explanations (Raduescu & Vessey, 2009). The retroduced explanations need to be empirically corroborated or validated (Wynn & Williams, 2012). Alternatively, the least plausible causal mechanisms can also be eliminated, and thus leaving the most plausible causal explanations as to the possible candidate propositions (Bygstad et al., 2016; Wynn & Williams, 2012). This is a type of critical realist middle-range theorizing (Ononiwu et al., 2018).

3.3 Data collection methods

The study mainly relies on the extant theory for both data collection and analysis (Bygstad et al., 2016; Ononiwu et al., 2018; Raduescu & Vessey, 2009; Wynn & Williams, 2012). However, to confirm the causal explanations, empirical corroboration is required by other relevant and complementary methods (Wynn & Williams, 2012). *Artefact analysis* will be used to empirically corroborate the proposed causal explanations of the affordance phenomenon (Norum, 2008, pp. 23–26). Artefacts can be used to enrich studies by providing additional information not readily available from surveys, interviews, or any other observational data (Norum, 2008, pp. 23–26). In the current context, the use of an artefact is deemed appropriate for purposes of exploring the available artifact features and their afforded possible actions to relevant abilities of social agents (Norum, 2008, pp. 23–26).

The extant theory will drive the *retroductive* research process involving the six-stages (see Figure 8): (i) *explication of events*; (ii) *explication of structure and context*; (iii) *retroduction*; and (iv) *empirical corroboration* (Wynn & Williams, 2012). The empirical corroboration will involve analysing the interactions of a typical social actor with an advanced smartphone digital device to explore the actions afforded by the features and the required performances required by the social actors to enact those feature actions (Wang et al., 2016). Thus, the method to be used for empirical corroboration will be the artefact study method (Goldkuhl, 2019).

3.4 Research instrument

As noted before the research is an explanatory research and hence the bulk of the study will involve theoretical analysis. In the main, the research involves critical realist middle-range theorizing (Ononiwu et al., 2018). For the critical realist middle-range theorizing portion of the research, the study employs the “model for selecting background theories” (Ononiwu et al., 2018, p. 9). The model involves theorising from literature reviews by following a systematic process of selecting, comparing, synthesising, and proposing theories (Okoli, 2015b, 2015a; Ononiwu et al., 2018; Rycroft-Malone et al., 2012).

The empirical corroboration portion of the research will involve analysing the sociomaterial interactions to explore the actions afforded by the material (*features*) and the required performances (*ability*) required by the social actors to enact the afforded behaviours. The analysing of the actor-artefact interactions involves aspects of usability engineering (Hollingsed & Novick, 2007; Nielsen, 1994), in particular, the *heuristic evaluation* method, *formal usability inspection* method, and *feature inspection* method (Hollingsed & Novick, 2007; Nielsen, 1994).

The method will be applied on a smartphone device guided by the original equipment manufacturer (OEM) manual or specifications (Ruiz et al., 2011). The intention is not to assess the usability of the device but to establish what functionality is provided by the device (Hollingsed & Novick, 2007; Nielsen, 1994; Ruiz et al., 2011). The following logic will be applied in each lifeworld smartphone interaction in the assessment:

a) For each sociomaterial interactions (i.e. *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal*), the associated social performances (*abilities*) and artefact actions (*features*) need to be identified, described, and explained.
b) The necessity of each of the underlying elements of feature and ability in the successful accomplishment of each sociomaterial routine must also be established or explained. Various heuristics and modal logic can be used to assess the necessary conditions of sociomaterial interactions.

3.5 Procedure for data collection

The study explores the smartphone as a digital artefact, and hence the case data will be based on the observed features of the artefact (Wang et al., 2016). The data collection for the core abduction process will be the extant literature on features, ability, and the affordance construct (i.e. proposition 1-3) as well as *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* sociomaterial interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). The empirical corroboration part of the study will be based on case data observations (i.e. smartphone feature analysis).

The case data involve analysing the sociomaterial interactions to explore the actions afforded by the material (*features*) and the required performances (*ability*) required by the social actors to enact the afforded behaviours. The analysing of the actor-artefact interactions involves aspects of usability engineering (Hollingsed & Novick, 2007; Nielsen, 1994), in particular, the *heuristic evaluation* method, *formal usability inspection* method, and *feature inspection* method (Hollingsed & Novick, 2007; Nielsen, 1994).

3.6 Data analysis and interpretation

Extant literature will be used to analyse and interpret the data, following the critical realist paradigm of explanatory research. That is, the cogency of the identified or retroduced explanations will be interpreted and validated based on established extant literature (Raduescu & Vessey, 2009). Alternatively, the least plausible causal mechanisms can also be eliminated, and thus leaving the most plausible causal explanations as to the possible candidate propositions (Bygstad et al., 2016; Wynn & Williams, 2012).

3.7 Limitations of the study

As noted above, the current research is a *concrete* or intensive research critical realist explanatory study (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013), exploring the causal mechanisms of affordances as described using the affordance underlying *ability* and *feature* constructs (Chemero, 2003; Şahin et al., 2007). As a *concrete* or intensive type of critical realist research, the objective is not to propose broad generalisable theory but to propose case-specific explanations of affordance causal mechanisms (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013).

The causal explanations to be proposed, should be judged on their plausibility strength and not on their general applicability (Carlsson, 2012, 2011; Easton, 2010; Hu, 2018; Ononiwu et al., 2018; Sayer, 2010; Tsang, 2014; Williams & Karahanna, 2013; Wynn & Williams, 2012; Zachariadis et al., 2013). Due to time limitations, the *multimethod triangulation* step is excluded in favour of complete and valid concrete (intensive) research scope (Wynn & Williams, 2012). Such exclusion, however, does not

invalidate nor render the research incomplete (Sayer, 2010, pp. 157–162; Zachariadis et al., 2013).

3.8 Transferability and dependability

In this context, transferability relates to how applicable are the findings in different scenarios. Credibility refers to the validity of the findings, whilst dependability refers to the effectiveness of research execution.

3.8.1 *Transferability*

Critical realist explanations are not prescriptive propositions, but plausible explanations of observed phenomena (Easton, 2010; Sayer, 2010; Tsang, 2014; Wynn & Williams, 2012; Zachariadis et al., 2013). The causal explanations describe the events based on their causal mechanisms, contingent conditions of causality, as well as the underlying structural conjunctures involved in the causation (Easton, 2010; Sayer, 2010; Tsang, 2014; Wynn & Williams, 2012; Zachariadis et al., 2013). It is thus these contextual conjunctures surrounding the causal explanations that enable such explanations to be transferable to other similar contexts under the same structural conjunctures and contingent conditions (Wynn & Williams, 2012; Zachariadis et al., 2013).

The causal explanations are based on plausible conjunctures that are likely to cause the observed phenomena, and hence plausibility of propositions is the acceptance criteria for the explanations (Easton, 2010; Mingers & Standing, 2017; Tsang, 2014; Wynn & Williams, 2012). The logic of the causal explanations is that given similar structural conjunctures and contingent conditions, the causality of the events can either be explained or at least provide enough information to account for the anomalies (Easton, 2010; Sayer, 2010).

3.8.2 *Credibility*

The applications of foundational theory in the descriptions of events, structures, mechanisms and underlying structural conjunctures contributes towards the credibility of the explanations (Zachariadis et al., 2013). Furthermore, only the plausible causal

explanations backed by both theory and empirical corroboration in the case are accepted (Wynn & Williams, 2012; Zachariadis et al., 2013). Furthermore, to improve the credibility of the proposed causal explanations the following evaluations criteria is proposed (see Table 3):

Table 3 Causal factor evaluation criteria (adapted Wynn & Williams, 2012)

Criteria	Evaluation Procedure
Presence of causal factors in the context	• Confirm causal factor contextual relevance. • Confirm theoretical backing of the causal factors. • Confirm that causal factors are not just imaginary but potentially real (i.e. ensure validity and plausibility of causal factors)
Causativeness of the causal factors	• Confirm causal relevance of causal factors (i.e. ensure causal factors indeed are causally involved in the phenomenon). • Account for the actual causal contributions of the causal factors.
Causal factor cogency	• Confirm causal validity and relevance of the causal explanations • Confirm causal significance of the causal factor causality
Dependability of the causal factors	• Assess the causal necessity and causal sufficiency of the causal factors in the phenomenon • Assess causal succession and causal precedence of the causal factors in the phenomenon

3.8.3 *Dependability*

The design and detailed description of the case ensures that the interpretation of the results is properly situated and contextually explained. For instance, the case is structured in terms of the Layder's (1993) four layers case structuring framework: *context*; *setting*; *situated activity*, and the *self* (Carlsson, 2009; Eastwood et al., 2019). The structuring ensures that each case data is contextually and appropriately situated into its social practice context, usage setting o scenario, activity context, and individual involvement (Carlsson, 2009). For instance, an individual case behaviour or response may not be the same in different situated activity, setting and context (Carlsson, 2009).

The correct case structuring, credible retroduction process based on valid explication of context and structure will improve the dependability of the causal explanations (Carlsson, 2009; Eastwood et al., 2019; Wynn & Williams, 2012). The plausibility of

the causal explanations will also improve the dependability of the study (Easton, 2010; Tsang, 2014; Wynn & Williams, 2012).

3.9 Demographic profile of respondents

No respondents involved.

3.10 Ethical considerations

The study involves the analysis of a digital technology artefact (i.e. Smartphone) to explore the various afforded features. Thus, there are no human subjects involved in this study. The study involves abstract theoretical constructs explored through various constructions to develop an affordance model. The research, therefore, does not pose any ethical risks.

CHAPTER 4. PRESENTATION OF FINDINGS

The current study is an explanatory *critical realist* case study of a smartphone digital device artefact (Raduescu & Vessey, 2009; Easton, 2010; Carlsson, 2012; Wynn & Williams, 2012; Goldkuhl, 2019).

4.1 Introduction

The objective of the research is to clarify formally the relational nature of the *feature-ability* construct and its underlying actualising mechanisms, with the view of enhancing the understanding of affordances. The research is a critical realist case study of an artefact (Goldkuhl, 2019), the smartphone digital device in an ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016). The method employed in this study is a critical realist retroductive research process involving the steps: (i) *explication of events*; (ii) *explication of structure and context*; (iii) *retroduction*; and (iv) *empirical corroboration* (Wynn & Williams, 2012).

The *explication of events* involved the description of the case events in detail (Wynn & Williams, 2012). In the context of the critical realist perspective, the case events are the afforded action events or *concrete outcomes* (Bygstad et al., 2016; Volkoff & Strong, 2013). The relevance of this step in the study is to situate the affordance phenomenon in the cases.

The *explication of structure and context* involves describing the context of the cases (i.e. by implication the situated affordance phenomena), based on extant social structure theories (Raduescu & Vessey, 2009; Wynn & Williams, 2012). The extant social structure theories employed to describe the situated case affordance phenomena include *inter alia*; (a) the *morphogenetic approach* (Archer, 1995) or *morphogenetic structure-agency* interplay (Ononiwu & Brown, 2013); (b) the *micro-macro* structural transformations (Coleman, 1994; Hedström & Ylikoski, 2010); (c) the *socio-technical* structure (Leonardi, 2011, 2012; Gaskin et al., 2014)); as well as the (d) critical realist stratified nested structural analysis (i.e. real, actual, and empirical domain structural analysis) (Raduescu & Vessey, 2009; Wynn & Williams, 2012). The purpose of the *explication of structure and context* was to locate, explore, and explain

the underlying structural elements of feature and ability in the emergence of affordances.

The most plausible causal mechanisms to the identified case events were then retroduced in the *retroduction* step (Wynn & Williams, 2012). The *retroduction* step involved the description of the plausible causal explanations to the affordance phenomenon, by positioning both the *explananda* and *explanans* of the affordance phenomena (Wynn & Williams, 2012). Lastly, the cogency of the identified or retroduced causal explanations was empirically assessed in the empirical corroboration step (Wynn & Williams, 2012).

The *empirical corroboration* step involved the actual smartphone artefact case study (Goldkuhl, 2019), in an ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016). The artefact study took an observer perspective in the form: *What would an imagined social actor be able to do given the features of the smartphone device artefact?* Based on the critical realist ontology, structural elaboration, causal logic, and causal reasoning as outlined above, the findings below were made.

4.2 Ability structural elements

(**RQ1**): What are the underlying structural elements and causal mechanisms of the '*ability'* construct in the emergence of *affordances*?

The **underlying structural elements** of the '*ability'* construct are: (a) know-how $\boldsymbol{KH_S}$ knowledge re-described as the *structure*; (b) the procedural dexterity $\boldsymbol{P_S}$ re-described as *mechanism*; (c) motivation or intent $\boldsymbol{W_S}$ re-described as *mechanism reasoning*; (d) achievement $\boldsymbol{A_S}$ re-described as a social event or outcome of mechanism; (e) *state of affairs* $\boldsymbol{K_S}$ re-described as specified *conditions* (Dalkin et al., 2015; Easton, 2010; Ossorio, 2010, pp. 33–43, 53; Tsang, 2014).

The **causal mechanisms** of the '*ability'* construct in the emergence of *affordances* are the *conditional-causal-structure*: ($\boldsymbol{KH_S}$, $\boldsymbol{K_S}$) (i.e. *know-how* $\boldsymbol{KH_S}$ knowledge, under the specified *state of affairs* $\boldsymbol{K_S}$) as well as the social mechanism ($\boldsymbol{P_S}$, $\boldsymbol{W_S}$) or motivated *procedural dexterity* $\boldsymbol{P_S}$, with intention $\boldsymbol{W_S}$. The ***ability* causal mechanism** can cause the *social event* $\boldsymbol{A_S}$, described by causal explanation $\boldsymbol{Ce_1}$ as follows:

Ce₁*:** the *empirical social event* ***Aₛ is the observed actual *social event* ***Aₛ***, that is caused by social *mechanism* (***Pₛ,Wₛ***) of the ***KHₛ*** social *structure* under specified ***Kₛ*** social *conditions* (i.e. pure social conjunctures without material technology artefact contribution).

4.3 Feature structural elements

(**RQ2**): What are the underlying structural elements and causal mechanisms of the '*feature'* construct in the emergence of *affordances*?

The **underlying structural elements** of the '*feature'* construct are: (a) component technology *entity* ***Exꜰ*** was re-described as the *structure*; (b) *action* ***Aꜰ*** re-described as *mechanism*; (c) *results* ***Rꜰ*** re-described as event or outcome of mechanism; (d) *preconditions* ***Prꜰ*** re-described as specified *conditions*; and (e) the *object* ***Oꜰ*** involved or used in *action* ***Aꜰ*** (a mechanism), was re-described as *mechanism resource* (Asnina, 2013; Dalkin et al., 2015; Easton, 2010; Osis et al., 2008, 2007; Solomencevs, 2016; Tsang, 2014).

The **causal mechanisms** of the '*feature'* construct in the emergence of *affordances* are the *conditional-causal-structure*: (***Exꜰ***, ***Prꜰ***) (i.e. component technology entity ***Exꜰ*** under specified *preconditions* ***Prꜰ***), as well as the mechanism (***Aꜰ***,***Oꜰ***) or entity action ***Aꜰ*** involving action linked *object* ***Oꜰ***. The ***feature* causal mechanism** can cause the *material event* ***Rꜰ***, described by causal explanation ***Ce₂*** as follows:

> ***Ce₂*:** the *empirical material event* ***Rꜰ***, is the observed actual *material event* ***Rꜰ***, that is caused by *material mechanism* (***Aꜰ***,***Oꜰ***) of the ***Exꜰ*** *material structure*, under specified ***Prꜰ*** *material conditions*. These are pure *material* conjunctures without social agency contributions.

4.4 Affordance emergence

(**RQ3**): How do *affordances* emergence from the underlying structural elements and causal mechanisms of the '*feature'* and '*ability'* constructs? Affordances are relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013). As relational action potentials,

affordances have been conceptualised from three perspectives: *agent*, *environment*, and *observer* perspectives (Cakmak et al., 2007; Şahin et al., 2007; Zech et al., 2017). In the context of an engaged social actor interacting with technology, the relevant affordance perspective for such interaction is the agent perspective (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

However, in terms of structure and logic of causal explanations, an observable *event* is caused by a *mechanism* enabled by a *structure*, subject to *contingent conditions* (Easton, 2010, p. 122). Affordances are also generative mechanisms capable of generating events or *concrete outcomes* (Bygstad et al., 2016; Volkoff & Strong, 2013). In terms of the critical realist logic, affordances are implied in the causal explanations of events as conditional event causation potentialities (Bygstad et al., 2016; Volkoff & Strong, 2013).

Affordances are emergent or caused by the interaction of (a) '***ability' conditional-causal-structure*** (***KH*$_S$**,***K*$_S$**) (i.e. *know-how* ***KH*$_S$** knowledge, under the specified *state of affairs* ***K*$_S$**), as well as the social mechanism (***P*$_S$**,***W*$_S$**) or motivated *procedural dexterity* ***P*$_S$**, with intention ***W*$_S$**; (b) interacting with '***feature' conditional-causal-structure***: (***Ex*$_F$**, ***Pr*$_F$**) (i.e. component technology entity ***Ex*$_F$** under specified *preconditions* ***Pr*$_F$**), as well as the mechanism (***A*$_F$**,***O*$_F$**) or entity action ***A*$_F$** involving action linked *object* ***O*$_F$**. The combined *actor-artefact* structural interaction causes the emergence of the sociomaterial *mechanism*: (***A*$_F$**,***O*$_F$**,***P*$_S$**,***W*$_S$**).

In the context of digital technologies, affordances (digital technology affordances) are emergent or caused by *feature-ability* interactions involving any of the possible digital communicative interactions — *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). Thus, the structural interactions, cause the emergence of the combined *actor-artefact* sociomaterial *mechanism*: (***A*$_F$**,***O*$_F$**,***P*$_S$**,***W*$_S$**), that can cause the following afforded *social event* ***A*$_S$**, *material event* ***R*$_F$**, and/or *sociomaterial event* (***R*$_F$**,***A*$_S$**) under appropriate *contingent* digital technology *conditions*, and described by following causal explanations (i.e. ***Ce*$_1$**, ***Ce*$_2$**, ***Ce*$_3$**, ***Ce*$_4$**, ***Ce*$_5$**, ***Ce*$_6$**, ***Ce*$_7$**, and ***Ce*$_8$**):

Ce₁*:** the *empirical social event* ***A_S is the observed actual *social event* ***A_S***, that is caused by social *mechanism* (***P_S,W_S***) of the ***KH_S*** social *structure* under specified ***K_S*** social *conditions*. These are pure social conjunctures without material technology contributions.

Ce₂*:** the *empirical material event* ***R_F, is the observed actual *material event* ***R_F***, that is caused by *material mechanism* (***A_F***,***O_F***) of the ***Ex_F*** *material structure*, under specified ***Pr_F*** *material conditions*. These are pure *material* conjunctures without social agency contributions.

Ce₃*:** the *empirical social event* ***A_S is the observed actual *social event* ***A_S***, that is caused by the *sociomaterial* structural *mechanism* (***A_F***,***O_F,P_S,W_S***) emerging from the *material structure* ***Ex_F*** *and* the social *structure* ***KH_S*** under specified ***K_S*** social *conditions*.

Ce₄*:** the *empirical material event* ***R_F is the observed actual *material event* ***R_F***, caused by the *sociomaterial* structural *mechanism* (***A_F***,***O_F,P_S,W_S***) emerging from the *material structure* ***Ex_F*** *and* the social *structure* ***KH_S*** under specified ***Pr_F*** *material conditions*.

Ce₅*:** the *empirical sociomaterial event* (R_F***,***A_S***), is the observed actual *sociomaterial event* (***R_F***,***A_S***) caused by the *sociomaterial* structural *mechanism* (***A_F***,***O_F,P_S,W_S***) emerging from the *material structure* ***Ex_F*** *and* the social *structure* ***KH_S*** under specified *sociomaterial conditions* (***Pr_F***,***K_S***).

Ce₆*:** the *empirical sociomaterial event* (R_F***,***A_S***), is the observed actual *sociomaterial event* (***R_F***,***A_S***), caused by incidental *sociomaterial* concurrence of causal explanation ***Ce₁*** and ***Ce₂***.

Ce₇*:** the *empirical social event* ***A_S, is the *empirical* misinterpretation of causal explanation ***Ce₅*** and/or ***Ce₆*** in favour of social causality.

Ce₈*:** the *empirical material event* ***R_F, is the *empirical* misinterpretation of causal explanation ***Ce₅*** and/or ***Ce₆*** in favour of material causality.

4.5 Summary of the findings

Affordances are relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013). Affordances are also conditional event causing potentialities, and hence the descriptions of affordances need to explicitly describe their event causing conditions. To express the conditionality of afforded actions, in the logic of the retroduced critical realist causal explanans, it is proposed that instead of formula [Aff1] the agent affordance formalism be expressed as formula [Aff1.1] below (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

> ***where affords*-ϕ** refers to the combined *actor-artefact mechanism* or sociomaterial mechanism (***A**F*,***O**F*,***P**S*,***W**S*);
>
> ***where feature*** refers to the *conditional-causal-structure* of component technology *entity* ***Ex**F* (*structure*), with its contingent conditionality ***Pr**F*, i.e. (***Ex**F*, ***Pr**F*);
>
> ***where ability*** refers to the *conditional-causal-structure* of social actor know how ***KH**S* (*structure*), with its contingent conditionality ***K**S*, i.e. (***KH**S*,***K**S*); ***and thence***.

affordance = (***A**F*,***O**F*,***P**S*,***W**S*) ((***Ex**F*, ***Pr**F*), (***KH**S*,***K**S*)) [Aff1.1]

The *feature* and *ability* constructs are respectively expressed as; *conditional-causal-structure* (***Ex**F*, ***Pr**F*) for technology and (***KH**S*,***K**S*) for the social actor. However, to reflect the *social* and *material* mechanism interaction, the combined *actor-artefact mechanism*: (***A**F*,***O**F*,***P**S*,***W**S*) is proposed. As previously noted, the "*structures and their associated mechanisms are ontologically decoupled from the events they produce*" (Tsang, 2014, p. 176).

Hence the events (i.e. ***A**S* or ***R**F*) are not included in the expression. Furthermore, the structure has contingent conditions upon which to enable the mechanisms, hence the contingent conditions are linked to the structure forming a *conditional-causal-structure* tuple (***KH**S*,***K**S*) for *ability conditional-causal-structure* or (***Ex**F*, ***Pr**F*) for *feature conditional-causal-structure.*

CHAPTER 5. DISCUSSION OF THE FINDINGS

In this chapter, the explanations of the finding are discussed. The discussions follow an explanatory logic based on the critical realist research method conducted, and the cumulative findings in each step, leading to the overall research findings already outlined.

5.1 Introduction

As previously noted, the purpose of the research is to clarify formally the relational nature of the *feature-ability* construct and its underlying actualising mechanisms, with the view of enhancing the understanding of affordances. The research conducted involved a critical realist case study of an artefact (Goldkuhl, 2019), i.e., the smartphone digital device in an ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016). The discussions will follow the critical realist research method steps conducted to trace the origin of the reasons behind the overall research findings already outlined. Thus, the discussions are organised into the following section: section 5.2 (*explication of events*); section 5.3 (*explication of structure and context*); section 5.4 (*retroduction*); and section 5.5 (*empirical corroboration*) (Wynn & Williams, 2012).

Section 5.2 outlines how the affordance phenomenon was situated in the artefact case study as well as how the case events were framed for empirical corroboration. Section 5.3 structurally locates, contextually explore, and explain the underlying structural elements of feature and ability in the emergence of affordances, based on various extant structural analysis theories (e.g. *morphogenetic approach*; *micro-macro* structural transformations; *socio-technical* structure; and the critical realist stratified structure). Section 5.4 describes how the affordance causal mechanisms were retroduced plausible causal explanations to the affordance phenomenon, by positioning both the *explananda* and *explanans* of the affordance phenomena (Wynn & Williams, 2012). Section 5.5 evaluates the causal propositions both empirically and theoretically.

5.2 Explication of events

In the *explication of events* or *description step* the events for which the causal mechanisms are to be explained were identified (Wynn & Williams, 2012). As noted elsewhere, events are specific occurrences of interest, caused by mechanism(s) (Wynn & Williams, 2012). The *explication of events, therefore,* involves describing the cases in detail to situate the affordance phenomena and related events for further analysis (Easton, 2010; Wynn & Williams, 2012; Zachariadis et al., 2013).

5.2.1 *Case context*

The case study involves an imagined ordinary engaged social actor in *lifeworld* settings (Basden, 2009; Beeson, 2001) using a smartphone device (Wang et al., 2016). The social actor is engaged in various episodes of human-technology digital interaction. The type of human-technology interactions anticipated and implied in this regard are the equivalents of the information systems (IS) *elementary interaction loop*, albeit not the same (Goldkuhl et al., 2004). The IS *elementary interaction loop* represents a single episode of human-technology interaction, which can either be a *reading*, *formulation*, or *navigation* episode (Goldkuhl et al., 2004).

In the current case of digital human-technology (i.e. smartphone-user), the interaction is not just informational, but broadly behavioural and experiential (Bowen & Giannini, 2014). The experiential nature of such interaction involves what is referred to as the *experiential* computing phenomenon (Yoo, 2010). *Experiential* computing human-technology interactions are more involving than other forms of computing phenomena such as *representational* computing and *imagined* computing (Yoo, 2010).

Experiential computing involves *perceptual*, *motor-activity*, *functional*, and/or *purposive* technology-user interactions, that are experienced or manifested through *space*, *time*, *actor*, and *artefact* dimensions (Yoo, 2010). The smartphone device was selected for the current study because it was deemed digitally archetypal as well as capable of supporting *experiential computing* (Yoo, 2010). In the current study the smartphone device is also positioned as a useful proxy artefact for digitality (digital culture) and/or digitalism (digitalisation of society) enquires (Bowen & Giannini, 2014).

5.2.2 *Case scenarios*

The types of human-technology interactions involving the *experiential computing space*, *time*, *actor*, and *artefact* experiential dimensions include *inter alia*: *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* communicative interactions (Table 4) (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011).

Table 4 Experiential computing communicative interactions

Interaction	**Description**	**Dimension** (Yoo, 2010)	**Source**
Chronemic	Time-based or timing based communicative interactions	*Time; Actor; Artefact*	Saunderson & Nejat, 2019
Proxemic	Spatiotemporal or spatial distance related communicative interactions	*Space; Actor; Artefact*	Hans & Hans, 2015; Saunderson & Nejat, 2019; Singh, 2011
Kinesic	Body movements, gestures, positions, gazes, and appearances related to communicative interactions	*Actor; Artefact*	Feine et al., 2019; Saunderson & Nejat, 2019
Haptics	Communicative tactility or touch-based communicative interactions	*Actor; Artefact*	Feine et al., 2019; Saunderson & Nejat, 2019
Oculesic	Eye kinesics or eye behaviours, gazes and other communicative interactions based on ocular expression	*Actor; Artefact*	Singh, 2011
Vocalic/ Verbal	Vocal intonations and auditory vocalisation based communicative interactions	*Actor; Artefact*	Feine et al., 2019
Textual	Text-based (e.g. command prompt) communicative interactions	*Actor; Artefact*	Feine et al., 2019

The *time* dimension (Yoo, 2010) relates to *chronemics* or timing-based human-technology interactions (Saunderson & Nejat, 2019). The *space* dimension (Yoo, 2010) relates to *proxemics*, which are the spatiotemporal or spatial distance-related communicative human-technology interactions (Hans & Hans, 2015; Saunderson &

Nejat, 2019; Singh, 2011). The *actor* and *artefact* dimensions (Yoo, 2010) relates to *kinesics* (i.e. communicative body movements, gestures, positions, gazes, and appearances); *haptics* (i.e. communicative tactility); *oculesics* (Singh, 2011) or eye *kinesics* (i.e. communicative eye behaviours, gazes, and other ocular expressions); and v*ocalics* or voicings and verbal human-technology interactions (Feine et al., 2019; Saunderson & Nejat, 2019). The *actor* and *artefact* dimensions (Yoo, 2010) also include ordinary *text-based* communicative modalities (Feine et al., 2019). The case, therefore, explores various *experiential computing* episodes of human-technology interactions or simply digital human-technology interactions (Yoo, 2010).

By *experiential computing* episode, is implied the communicative human-technology interaction instances involving *space*, *time*, *actor*, and *artefact* experiential dimensions (Yoo, 2010). For purposes of the current study, each episode of *experiential computing* involves at least one instance of *chronemic*, *proxemic*, *kinesics*, o*culesic*, v*ocalic*, *textual*, and *verbal* communicative modalities (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). Furthermore, each *experiential computing* episode involves at least one instance of digital technology affordances (Autio et al., 2018; Nambisan et al., 2017; Yassaee & Winter, 2017). By digital technology affordances, it is meant the affordances of technologies supporting *experiential computing* (Yoo, 2010). That is, technologies that support *space*, *time*, *actor*, and *artefact* experiential dimensions as previously described (Yoo, 2010).

5.2.3 *Case framing*

The current case involves explaining the causal mechanisms of *digital technology affordances* (Autio et al., 2018; Nambisan et al., 2017; Yassaee & Winter, 2017) through the use of digital technologies (Berger et al., 2018). To frame the case study, Layder's (1993) framework of social action and social organisation is adopted (Carlsson, 2009; Eastwood et al., 2019). Layder's (1993) framework classifies social phenomena into four layers: *context*; *setting*; *situated activity*, and the *self* (Carlsson, 2009; Eastwood et al., 2019). In the current context the case is structured as follows:

a) ***Case Context***: the context is the societal context of a case (Carlsson, 2009). In the current study, the context is limited to *experiential computing* (Yoo, 2010) aspects of *digitalism* (Bowen & Giannini, 2014). *Experiential* computing is

concerned with *perceptual*, *motor-activity*, *functional*, and/or *purposive* technology-user interactions, that are experienced or manifested through *space*, *time*, *actor*, and *artefact* dimensions (Yoo, 2010).

b) ***Case Setting***: the setting is the "immediate arena for social activities" (Carlsson, 2009, p. 64). Thus in the current case, the setting involves the *routine* use of digital technology by social actors in everyday ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016). More specifically the setting involves the *digitality* or digital culture of smartphone use (Bowen & Giannini, 2014).

c) ***Case Situated Activity***: the *situated activity* involves the types or nature of social involvement as well as the types of interactions in the setting (i.e. smartphone use situated activity settings) (Carlsson, 2009). In the current case, the situated activities various experiential computing episodes of human-technology interactions (i.e. *space*, *time*, *actor*, and *artefact* experiential interactions) (Yoo, 2010).

d) ***Case Self***: the actual behaviour of the social actor in the situated activity represents the self (Carlsson, 2009). It is the nuanced actual social contribution in the interaction. It describes what is required from the social actor for a successful interaction. In the current case, the self describes what form of eye gaze, hand gesture, touch, tone, intonation, etc. is required for the interaction.

The separation of case concerns based on the layers of the Layder (1993) framework, will ensure that each case observation is understood and appropriately interpreted based on its contextual aspects. For instance, the observations in the current case will be based on the actual 'self' behaviour in the various situated experiential interactions (*situated activity*) of 'everyday digitality' (*setting*) within the broader experiential computing practice (*context*).

5.2.4 *Case design*

As noted previously, case observations will involve the actual 'self' behaviour of the engaged imagined social actor, interacting with the material artefact. The approach will be in the format: '*What would the social actor do given the features of the artefact?*' However, considering that affordances involve goal-directed behaviour as opposed to aimless fiddle, the case analysis units also need to be limited to goal-directed behaviour as well (Volkoff & Strong, 2013). To locate and situate affordances, it is proposed that the *sociomaterial routine* construct be used as the situating construct for case analysis (Gaskin et al., 2014). By *sociomaterial routine* is meant the purposeful *interaction* of interrelated *activities* involving the *social* and *material* elements within a *sociomaterial practice* (Gaskin et al., 2014; Leonardi, 2011). *Sociomaterial routines* are constituted of *activities* each involving a distinct social *actor*, using a material *tool*, affording certain *affordances* for a particular purpose (Gaskin et al., 2014). Affordances are thus emergent sociomaterial situated phenomena (Gaskin et al., 2014).

Sociomateriality is a " …*powerful and prominent ontological lens to explore the mutually constitutive and emergent relationship between humans and nonhuman technologies*" (Gaskin et al., 2014, p. 850). *Sociomaterial practices* (Gaskin et al., 2014; Orlikowski, 2007), are spaces within a broader *socio-technical system* (Leonardi, 2012), where the *social* and *material* are *entangled* (Orlikowski, 2006, 2007) or *imbricated* with each other (Leonardi, 2011, 2012, 2013a). *Sociomaterial practices* (Orlikowski, 2007) are constituted of *sociomaterial routines* (Gaskin et al., 2014).

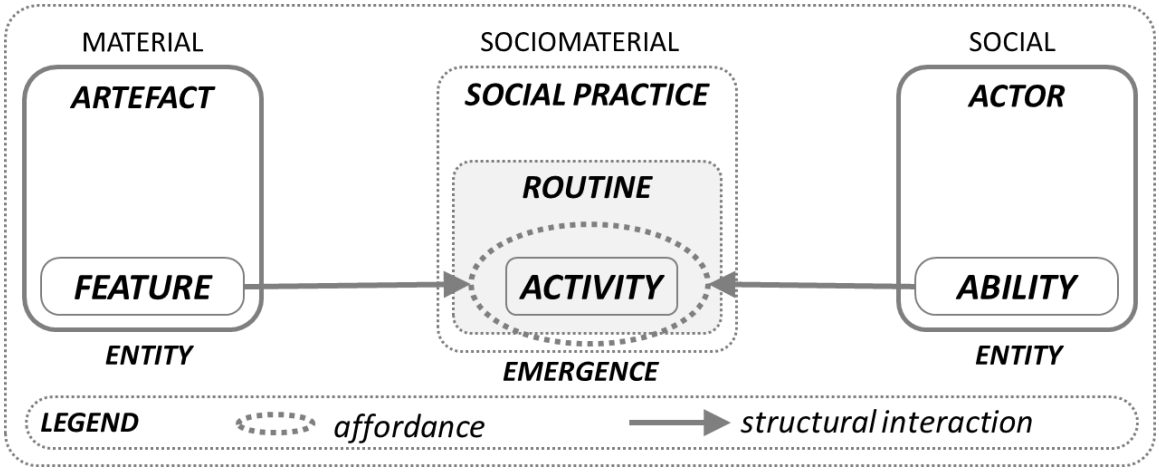


Figure 9 The situated affordances in a sociomaterial routine

In the current study, the *sociomaterial routine* construct is the affordance situating construct and contextualising mechanism to analyse purposeful *sociomaterial* interactions (Figure 9) (Gaskin et al., 2014). For this purpose, the experiential computing practice is viewed as the *context layer*, the sociomaterial routine as the *setting*, and its underlying constitutive activities as the *situated activities* (Carlsson, 2009; Gaskin et al., 2014).

The users or social actors interact with technology in social use situations through the affordances that the technology affords such users (Bernhard et al., 2013; Evans et al., 2017; Markus & Silver, 2008). The affordances afforded by technology to its users are considered to be part of the generative elements of *sociomaterial routines* (Gaskin et al., 2014). This is because affordances are emergent *action possibilities* resulting from *material to social* and/or *social to material imbrications* (Leonardi, 2011). Thus, affordances are deemed to be enacted within *sociomaterial routines* (Gaskin et al., 2014), which are part of the *sociomaterial* structure or sub-system (Leonardi, 2011, 2012).

5.3 Explication of structure and context

The *explication of structure and context* (Wynn & Williams, 2012) includes a*nalytical resolution* and *theoretical re-description* (Raduescu & Vessey, 2009). It is the critical realist *analytical resolution* (Raduescu & Vessey, 2009) or the description of the situation and locating of the event-causal structure in the three domains of stratified nested existence (i.e. real, actual, and empirical) (Raduescu & Vessey, 2009; Wynn & Williams, 2012). The section involves locating structurally the underlying structural elements of feature and ability in the emergence of affordances.

The section involves *inter alia* the following theoretical foundations: (a) the *morphogenetic approach* (Archer, 1995) or *morphogenetic structure-agency* interplay (Ononiwu & Brown, 2013); (b) the *micro-macro* structural transformations (Coleman, 1994; Hedström & Ylikoski, 2010); (c) the *socio-technical* structure (Leonardi, 2011, 2012; Gaskin et al., 2014); and (d) the critical realist stratified nested structural analysis (i.e. real, actual, and empirical domain structural analysis) (Raduescu & Vessey, 2009; Wynn & Williams, 2012).

5.3.1 *Social structure*

In terms of the critical realist perspective, causal explanations to phenomena can be inferred by identifying interactional mechanisms among the underlying structural *entities* in context (Wynn & Williams, 2012). The existential reality of entities is supported *entity realism* (Chakravartty, 2007, pp. 27–33). However, in terms of the *semirealist stance* (Chakravartty, 2007, pp. 39–48), *entities* can be things (i.e. organisations, people, artefacts, relationships, language, attitudes, resources, ideas, etc.), with event enabling causal powers and liabilities (i.e. mechanisms) (Easton, 2010). That is, entities may be structures themselves (viz. *ontic structural realism*) or may be related to one another in structural formations through necessary relations (viz. *epistemic structural realism*) (Chakravartty, 2007, p. 34; Easton, 2010).

Interactions among the existential *structures*, *entities* and/or generative causal *mechanisms* in the real domain lead to actual *events* in the *actual* domain, that may or may not be observable as empirical *events* in the *empirical* domain (Mingers & Standing, 2017; Sorrell, 2018; Volkoff & Strong, 2013; Wynn & Williams, 2012). Mechanisms are the *causal powers* or *tendencies*, whilst *events*, are specific occurrences of interest, caused by mechanism(s) (Wynn & Williams, 2012). Furthermore, mechanisms may also require or may involve mechanism *reasonings* and/or mechanism *resources* (Dalkin et al., 2015).

To depict the causal nature of the structures and their mechanisms, the mechanism-based conception of structure will be useful (Coleman, 1994; Hedström & Ylikoski, 2010; Matsueda, 2017; Mayntz, 2004; Ononiwu & Brown, 2013). In terms of the mechanism-based view, and also from the *critical naturalist stance* (Archer et al., 1998, pp. xiii–xvii), the individual level behaviour (‘micro’ structure) constitutes the ‘macro’ social context, whilst equally constrained and/or enabled by the same (Coleman, 1994; Hedström & Ylikoski, 2010). The mechanism-based view embodies and can be explained by the *transformational model* of *social activity* (TMSA) (Archer et al., 1998, pp. xiii–xvii). The mechanisms involved in the mechanism-based view, include the enabling and/or constraining: (a) *situational* mechanisms (macro-micro); (b) *action-formation* mechanisms (micro-micro); the (c) *transformational* mechanisms (micro-macro); and (d) *macro-level association* mechanisms (macro-macro) (see Figure 13) (Hedström & Ylikoski, 2010).

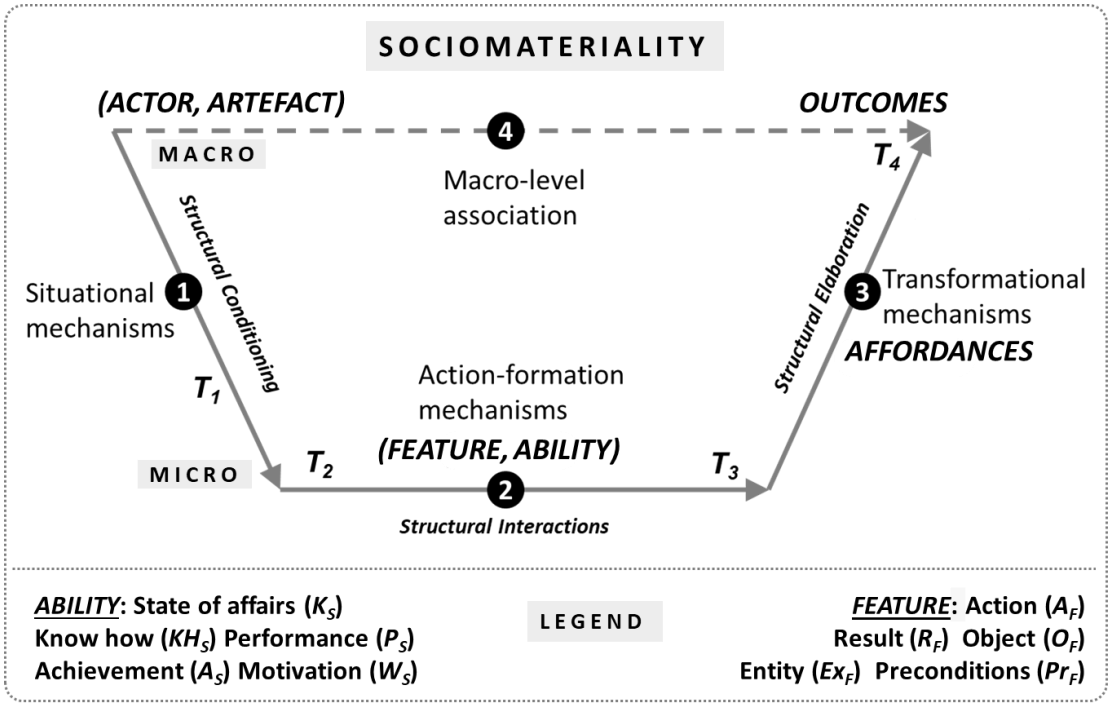


Figure 10 Macro-micro mechanism-based structure

(adapted Coleman, 1994; Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013)

The macro-level *situational* mechanisms condition individual behaviour at the micro-level through *structural conditioning* (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013). The *structural interactions* among the individual members in the 'micro' structure involve the *action-formation* mechanisms (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013). When the cumulative micro-micro *structural interactions* cause the micro-macro structural transformations (*structural elaboration*), the *transformational* mechanisms emerge (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013).

In the current study, the '*macro'* structure is the *social practice* instantiation of the *actor-artefact* relational system (see Figure 11), and part of the *socio-technical system* (Leonardi, 2011, 2012, 2013a). The *features* and *abilities* involved in the *actor-artefact* interactions are the '*micro'* structure, and they are the focus of the current study. The *action-formation* mechanisms of the *features* and *ability* structural interactions are thus the focus of this study (see Figure 13). As previously noted, the *transformational* mechanisms develop when the micro-micro *structural interactions* through *structural elaboration*, cause the micro-macro structural transformations (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013).

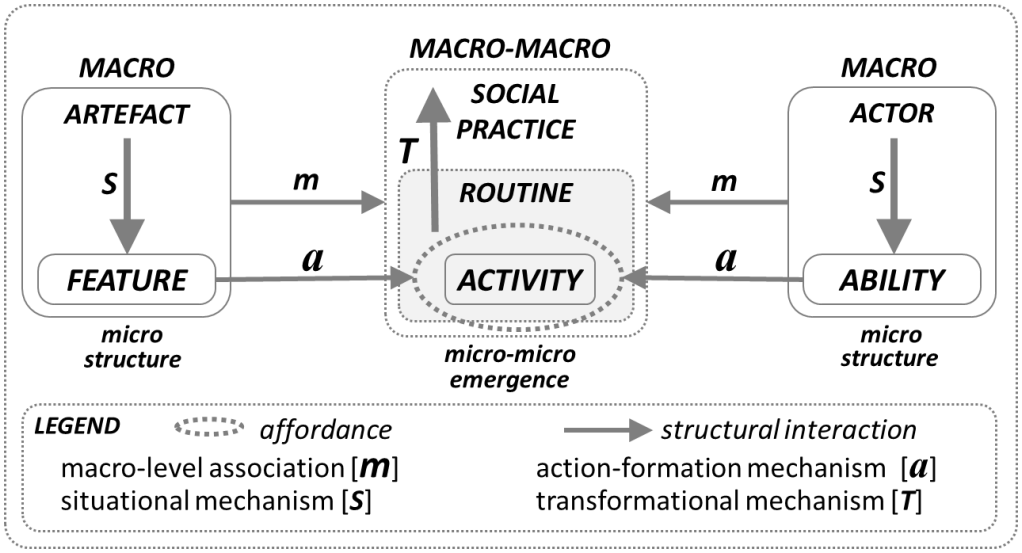


Figure 11 Macro-micro mechanism-based structural transformations

The cumulative effect of the micro-level *action-formation* mechanisms (i.e. *features* and *ability* structural interactions) thus becomes the *affordance transformational* mechanisms (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013). The *affordance transformational* mechanisms, on the other hand, transforms the 'macro' structure by achieving concrete goals or events (Bygstad et al., 2016; Volkoff & Strong, 2013).

5.3.2 *Macro structure*

Actors and their artefacts including other forms of entities in the social context as well as their contextual social relations, constitute a *social structure* (Wynn & Williams, 2012). The contextual structural relations may include *inter alia*, language, culture, rules, practices, technological artefacts, and so forth (Wynn & Williams, 2012). Furthermore, the relation between the artefact (i.e. smartphone device) and the social actor also constitute a social structure (Wynn & Williams, 2012), albeit an *emergent sociomaterial* structure (Leonardi, 2011, 2012). In terms of the current case framing, the case involves an experiential computing *sociomaterial practice*, which can be viewed as part of the broader *socio-technical system* (STS) (Leonardi, 2012). The *socio-technical system* can be viewed as an interactional assemblage of the *social* and the *technical* or *sociomaterial* sub-systems (Figure 12) (Leonardi, 2012). The case thus involves *sociomateriality*, which is the *imbrication* (i.e. the reciprocal affecting) of the *social* and the *material* technology in use (Leonardi, 2011).

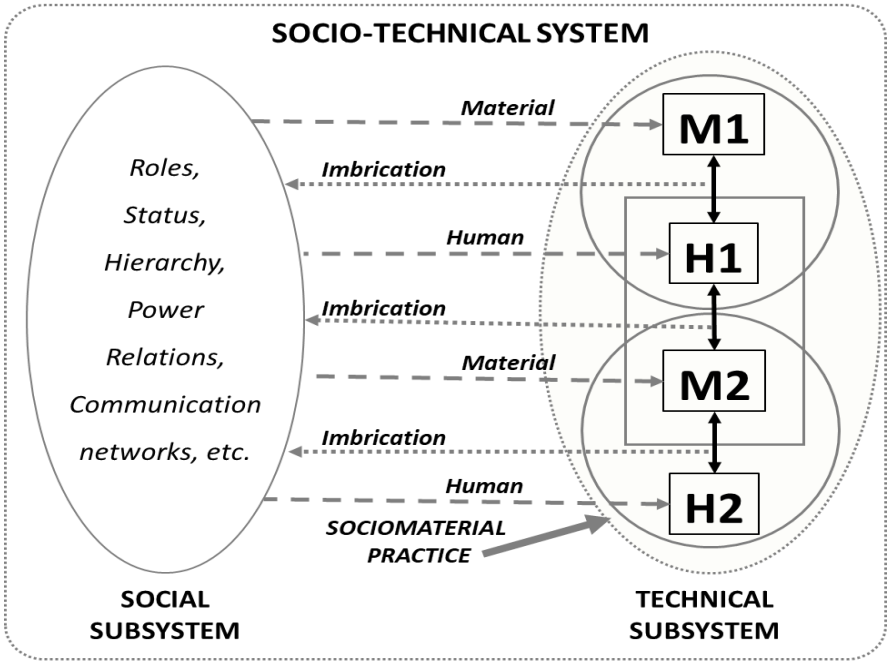


Figure 12 Socio-technical, social, and sociomaterial systems
(adapted Leonardi, 2011, 2012)

The *'social'* refers to human agency or human intentionality (Leonardi, 2011, 2012, 2013a). *Materiality* refers to the enduring morphological configurations of both digital and physical artefacts that are essential to artefact users (Leonardi, 2012, 2013a). *Sociomaterial imbrications* (Leonardi, 2011, 2012, 2013a) or *entanglements* occur within *social practices* (Gaskin et al., 2014; Orlikowski, 2007). The *imbrications* can be *material* (M) to *social* (H) and/or *social (H)* to *material (M) (e.g. M1→H1, H1→M2, M2→H2)* (see Figure 12) (Leonardi, 2011).

The current case involves an imagined ordinary social actor in *lifeworld* settings using a smartphone device (Wang et al., 2016). However, unlike corporate systems which may involve structured processes and standard operating procedures, the *lifeworld* use of technology is mainly a trial and error effort. Whilst in some instances, users may from time to time engage the original equipment manufacturer (OEM) provided manuals and feature specifications, the 'use' behaviour is largely emergent (Sun, 2012). However, the use of smartphones (digital technology) in ordinary *lifeworld* use settings (Basden, 2009; Beeson, 2001; Wang et al., 2016) largely involves emergent use behaviour (Sun, 2012). Emergent use behaviour may involve trial and error use (trying new features), feature substitution, feature combinations, and feature

repurposing (Sun, 2012). Furthermore, emergent use behaviour may also involve only a subset of the overall features — *features in use* (Sun, 2012).

To conceptualise the emergent use behaviour in the current case, the morphogenetic model of emergent technology use is adopted and adapted (see Figure 13) (Ononiwu & Brown, 2013). The purpose of adopting the emergent technology use model is to enhance the contextualisation of the case data, and subsequent reporting thereof. The adapted model (Figure 13) of emergent technology use, employs the same logic of the mechanism-based conception of structure (Coleman, 1994; Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013). The adapted model (Figure 13) of 'emergent technology use', describes a cyclic three-phase contextual technology use process: (a) *structural conditioning*; (b) *structural interactions*; and (c) *structural elaboration* (Ononiwu & Brown, 2013).

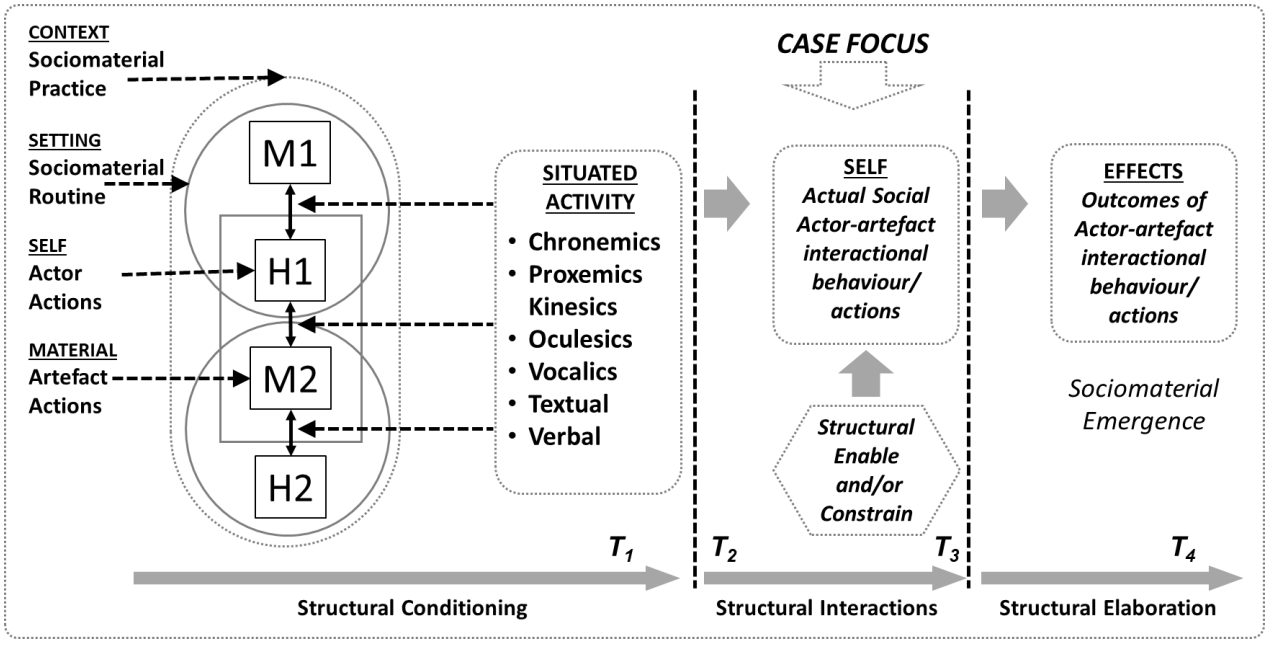


Figure 13 Morphogenetic model of technology emergent use behaviour

(adapted Layder, 1993; Leonardi, 2011, 2012; Ononiwu & Brown, 2013)

The adapted model situates the current case in the experiential computing sociomaterial practice (i.e. case *context*) (Layder, 1993; Carlsson, 2009; Eastwood et al., 2019; Orlikowski, 2007; Yoo, 2010). The *case setting* is the lifeworld smartphone routine use culture, which largely involves adaptive or emergent use behaviour (Sun, 2012; Wang et al., 2016). Thus, the case setting involves the plausible *sociomaterial*

routines applied by the imagined social actor engaged in the lifeworld smartphone routine use culture (Gaskin et al., 2014; Wang et al., 2016). *Sociomaterial routines, on the other hand,* are constituted of *activities* each involving a distinct social actor(s) (Gaskin et al., 2014).

The imagined social actor performs various routine *activities* on the smartphone device based on the features provided by the technology, as part of the plausible *sociomaterial routines* (Gaskin et al., 2014; Wang et al., 2016). The activities involve the *perceptual*, *motor-activity*, *functional*, and/or *purposive* technology-user interactions typical of the *space*, *time*, *actor*, and *artefact experiential computing* human-technology or actor-artefact interactions (Yoo, 2010). Thus the activities involve *inter alia*: the include *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* communicative interactions (see Table 4) (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011).

In the current case (Figure 13), the *context* (experiential computing); *setting* (emergent technology/ smartphone use culture); and *situated activity* (*chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* communicative interactions) are part of the predisposing macro structure conditioning the case '*self*' (Layder, 1993; Carlsson, 2009; Eastwood et al., 2019). Thus, the *context*, *setting*, and *situated activity* are part of the *structural conditioning* for the case episodes. The case itself (i.e. 'self') involves the ability-feature *structural interactions* of the social actor and the artefact. The affordances are thus part of *structural elaboration* (Ononiwu & Brown, 2013).

5.3.3 *Micro structure*

As noted previously, the prevailing social system ('macro' structure) tend to influence the way social agencies behave at the micro (individual 'self') level and the meanings they attach to their actions (Coleman, 1994; Hedström & Ylikoski, 2010). The 'macro' structure conditions (*structural conditioning*) the 'micro' structure by can either enabling or constraining behaviour or actions (Hedström & Ylikoski, 2010; Ononiwu & Brown, 2013). Similarly, the *structural interactions* of the agencies at the micro-level in return also changes the 'macro' structure — *structural elaboration* (Ononiwu & Brown, 2013).

Affordances, therefore, involve goal-directed actor-artefact *structural interactions* (Volkoff & Strong, 2013). In terms of Layder's (1993) framework, the actor represents the 'self' aspects of the case (Carlsson, 2009). The self-aspects are the actual behaviour or procedural involvement of the social actor in the interaction (i.e. situated activity) (Carlsson, 2009). The actor interaction self-behaviour is concerning the situated *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal* communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). However, considering that affordances involve goal-directed behaviour (Volkoff & Strong, 2013), their behavioural dispositions are essential for successful interactions (Bergner, 2010, 2016; Ossorio, 2010, 2013).

However as noted elsewhere, the actor interacts with the artefact through its functional features (Markus & Silver, 2008). The *ability* of the user or social actor to interact with the technology in such use settings involve the user's *know-how* $\boldsymbol{KH_S}$ knowledge to accomplish an *achievement* $\boldsymbol{A_S}$ by artefact usage *procedural dexterity* $\boldsymbol{P_S}$ motivated by *goal* $\boldsymbol{W_S}$ given the *state of affairs* $\boldsymbol{K_S}$ formalised as follows (see formula [Bh2]) (Ossorio, 2010, pp. 33–43, 53):

$$Ability = (\boldsymbol{W_S, K_S, KH_S, P_S, A_S}) \quad [Bh2]$$

However, the actor interaction with the artefact is through its functional features (Markus & Silver, 2008). The functional features are simply component technology *entities* $\boldsymbol{Ex_F}$ that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, using or involving an *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016). Put differently, the actor interacts with the technology component (see formula [Ff2]) *entity* $\boldsymbol{Ex_F}$ that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving an *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

$$feature = (\boldsymbol{A_F, R_F, O_F, Pr_F, Ex_F}) \quad [Ff2]$$

Given the five-parameter *ability* description ($\boldsymbol{W_S, K_S, KH_S, P_S, A_S}$); the five-parameter *feature* description ($\boldsymbol{A_F, R_F, O_F, Pr_F, Ex_F}$); as well as the involved communicative interactions (i.e. *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal*), the research conceptual framework (see Figure 1) can be revised and updated as outlined in Figure 14. The diagram in Figure 14 can be interpreted as an affordance

action potential relation for achieving *concrete outcomes* between goal-directed *actors* and *artefacts* (Volkoff & Strong, 2013).

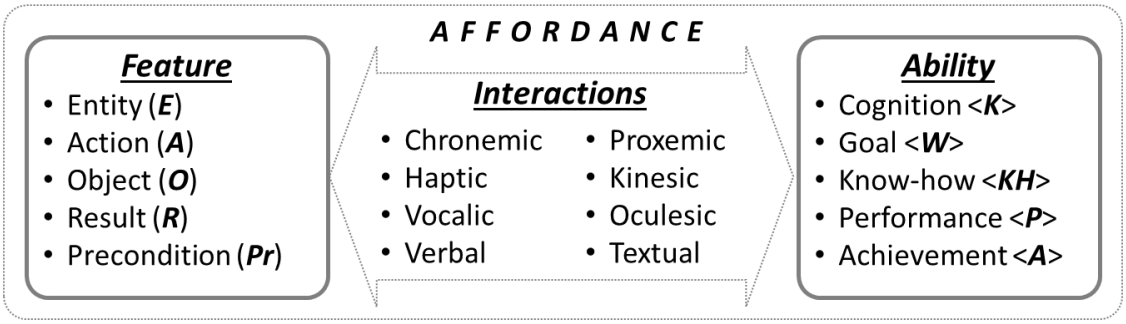


Figure 14 Experiential technology-user interactions

As an affordance relation the diagram in Figure 14 can be interpreted as an affordance interactional relation between the social actor through their *abilities* (***W*S, *K*S, *KH*S, *P*S, *A*S**) (Ossorio, 2010, pp. 33–43, 53), and the artefact features (***A*F, *R*F, *O*F, *Pr*F, *Ex*F**) (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016). The interactions being any of the *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and/or *verbal* communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011).

The actor-artefact interactions can also be described as *material*-to-*social* and/or *social*-to-*material imbrications* out of which affordances as relational action potentials emerge (Leonardi, 2011). The emergent action potential relation or *afforded behaviour* (i.e. *affords*-**ϕ**) formulation as described through the *feature* and *ability* descriptions can be expressed as follows (formula [Aff1]) (Chemero, 2003):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

where *affords*-**ϕ** refers to the *effect* (Chemero, 2003; Şahin et al., 2007);

where feature refers to technology component *entity* ***Ex*F**, that can achieve *results* ***R*F**, by executing an *action* ***A*F**, using or involving an *object* ***O*F**, given the *preconditions* ***Pr*F** (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016);

where ability refers to the *know-how* ***KH*S** knowledge of achieving an outcome or *achievement* ***A*S** by *procedural dexterity* ***P*S,** motivated by *goal* ***W*S** given the *state of affairs* ***K*S** (Ossorio, 2010, pp. 33–43, 53).

In summary, the ‘micro’ structure of the current case involves the social actor interacting with an artefact (i.e. digital smartphone) through its functional features (Markus & Silver, 2008). The *interaction* requires the user’s *know-how* $\boldsymbol{KH_S}$ knowledge to accomplish an *achievement* $\boldsymbol{A_S}$ by artefact usage *procedural dexterity* $\boldsymbol{P_S}$ motivated by *goal* $\boldsymbol{W_S}$ given the *state of affairs* $\boldsymbol{K_S}$ formalised as follows (see formula [Bh2]) (Ossorio, 2010, pp. 33–43, 53). The social actor interacts with the technology component (see formula [Ff2]) *entity* $\boldsymbol{Ex_F}$ that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving an *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

5.3.4 *Micro-interactions*

The *material* agency (artefacts) are both entities and also structures *sui generis* constituted by related individual *functional features* in a technology feature system (Asnina, 2013; Cheikh-Ammar, 2018; DeSanctis & Poole, 1994; Griffith, 1999; Markus & Silver, 2008; Osis et al., 2008, 2007; Osis & Asnina, 2011; Osis & Donins, 2017). Likewise, the *social* agency (social actor) are also both entities and structures *sui generis* made up of knowledge, language, personality traits, physiological structures, etc., (Easton, 2010; Öğütle, 2013).

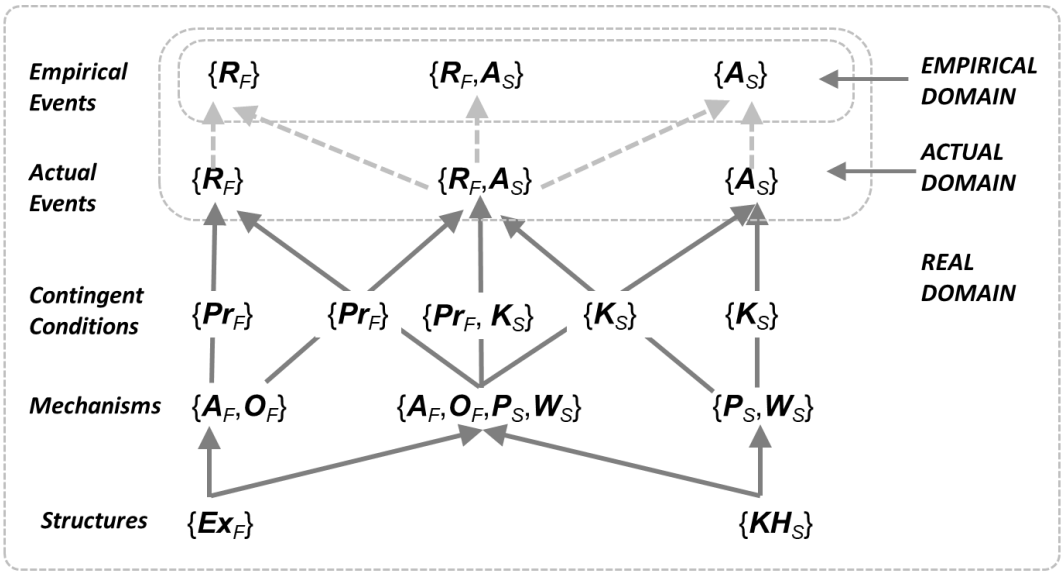
The affordance relevant aspects of digital technology *material* agency, from a reductionist *feature* perspective, can be described simply as component technology *entity* $\boldsymbol{Ex_F}$, that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving an *object* $\boldsymbol{O_F}$ (i.e. as resource or input in *action* $\boldsymbol{A_F}$), under *preconditions* $\boldsymbol{Pr_F}$ (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016). In the context of the critical realist conjunctures (i.e. *structure*, *mechanism*, *condition*, and *event*) the *features* can be re-described as follows, where:

> component technology *entity* $\boldsymbol{Ex_F}$ corresponds to the *structure*; *results* $\boldsymbol{R_F}$ to *events*; *action* $\boldsymbol{A_F}$ to *mechanism*; *preconditions* $\boldsymbol{Pr_F}$ to specified contingent *conditions* (Easton, 2010; Tsang, 2014). The *object* $\boldsymbol{O_F}$ involved or used in *action* $\boldsymbol{A_F}$ (a mechanism), can be considered an input resource or simply mechanism *resource* (Dalkin et al., 2015).

The affordance relevant aspects of the *social agency* from the *ability* reductionist perspective can be described as the *know-how* KH_S knowledge of achieving an outcome or *achievement* A_S by *procedural dexterity* P_S motivated by *goal* W_S given the *state of affairs* K_S (Ossorio, 2010, pp. 33–43, 53). In the of the critical realist context *ability* can be re-described as follows, where:

> *know-how* KH_S knowledge corresponds to the *structure*; the *achievement* A_S to *events*; *procedural dexterity* P_S to *mechanism*; the *state of affairs* K_S to specified contingent *conditions* (Easton, 2010; Tsang, 2014). Since W_S is the *motivation* for the *procedural dexterity* P_S (a mechanism), the *motivation* W_S could be considered the *mechanism reasoning* (Dalkin et al., 2015; Ossorio, 2010, pp. 33–43, 53).

The critical realist *feature* and *ability* re-descriptions are outlined in Figure 15. Furthermore, in the 'Figure 15' diagram, the *solid bold lines* represent possible *normative causal trajectory*, and the *dotted lines* represent possible *empirical* manifestations. *Empirical* manifestations, on the other hand, may or may not faithfully reflect the underlying actual events, and possibly this could be due to *empirical* misinterpretations or experiential limitations (Markus & Rowe, 2018).



ABILITY: State of affairs (K_S); Know how (KH_S); Procedural dexterity (P_S); Achievement (A_S) Goal (W_S); **FEATURE:** Action (A_F); Result (R_F); Object (O_F); Preconditions (Pr_F); Entity (Ex_F)

causality — empiricism

Figure 15 Theoretical re-description of feature and ability

However, affordances are relational action potentials (Volkoff & Strong, 2013) or emergent *sociomaterial* phenomena (Leonardi, 2011), emanating from '*feature'* (*entity*) and *ability* (*behaviour*) relations (Chemero, 2003; Şahin et al., 2007). In terms of the critical realist structural re-descriptions, the affordance construct, therefore, can be re-described or expressed as follows (formula [Aff1]) (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

where *affords*-**ϕ** refers to the *effect* (Chemero, 2003; Şahin et al., 2007);

where feature is component technology *entity* $\boldsymbol{Ex_F}$ (*structure*), that can achieve *results* $\boldsymbol{R_F}$ (*event*), by executing an *action* $\boldsymbol{A_F}$ (a *mechanism*), using an *object* $\boldsymbol{O_F}$ (mechanism resource), under *preconditions* $\boldsymbol{Pr_F}$ (specified *conditions*) (Asnina, 2013; Dalkin et al., 2015; Easton, 2010; Osis et al., 2008, 2007; Solomencevs, 2016; Tsang, 2014);

where ability is *know-how* $\boldsymbol{KH_S}$ *knowledge* (*structure*) of achieving outcome or *achievement* $\boldsymbol{A_S}$ (*event*), by *procedural dexterity* $\boldsymbol{P_S}$ (a *mechanism*) motivated by *goal* $\boldsymbol{W_S}$ (mechanism reasoning), under the *state of affairs* $\boldsymbol{K_S}$ (specified *conditions*) (Dalkin et al., 2015; Easton, 2010; Ossorio, 2010, pp. 33–43, 53; Tsang, 2014).

Furthermore, in terms of the critical realist causal reasoning, events are generated by *mechanisms* of *entities* and/or *structural conjunctures* but also through *mechanism interactions* (Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Sayer, 2010; Wynn & Williams, 2012). This implies that potentially social events are emanating from *social conjunctures*, *material events* from *material conjunctures*, but also *sociomaterial events* from *social* and *material mechanism interactions* in the current case (Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Sayer, 2010; Wynn & Williams, 2012).

5.4 Retroduction

The *retroduction* step involves the proposition of the most plausible causal mechanisms to the identified events (Wynn & Williams, 2012). It involves identifying the causal explanations from theoretical re-descriptions proposed (Raduescu & Vessey, 2009). It also involves finding alternate theories to explain the causal context (Raduescu & Vessey, 2009). According to Easton (2010), causal explanations need to account for the entities, their mechanisms, and the events they cause to occur.

5.4.1 *Causal explananda*

Affordances are types of generative mechanisms or a subset of generative mechanisms in the logical sense of critical realism or (Bygstad et al., 2016; Volkoff & Strong, 2013). Furthermore, affordances are the ever-present action potential that may be realised as events in the actual and/or empirical domain through goal-oriented actions (Volkoff & Strong, 2013). This implies that any relational *causal conjunctures* between goal-directed actors and artefacts in the real domain could count for affordances (Volkoff & Strong, 2013). That is, if the event-*causal conjunctures* involve goal-directed actors and artefacts, they could be considered as affordance *causal conjunctures* (Volkoff & Strong, 2013).

There could be several plausible causal mechanisms accounting for the *actual events* (i.e. *actual domain*) observed as *empirical events* (see Figure 15 and Figure 16) (Mingers, 2004; Mingers & Standing, 2017). Furthermore, the *social*, *material* or *sociomaterial* events observed in the empirical domain could also be caused by *social*, *material*, and/or *sociomaterial causal conjunctures* or possible combinations thereof (Tsang, 2014). Given that affordances involve outcomes of goal-directed actor-artefact relations, the question, however, is what is the nature of the actor-artefact or *sociomaterial* contributions that qualify as affordances? Meaning to what extent should the individual *social* and *material* conjunctures be present for the affordance phenomenon to hold?

For instance, there could be a 'goal achievement' *social event* $\boldsymbol{A_S}$ that is empirically observed but caused by any of the *social*, *material*, and/or *sociomaterial conjunctures* (Tsang, 2014). Would such an observed *social event* $\boldsymbol{A_S}$ be considered an *affordance*

phenomenon or just an outcome of social action? Similarly, what about an observed *material event* $\boldsymbol{R_F}$, independently caused by material conjunctures alone, that purportedly meet some 'goal achievement' *social event* $\boldsymbol{A_S}$? Would such an observed *material event* $\boldsymbol{R_F}$, be considered an *affordance* event or it will be considered a mere technology action result that happens to meet a social goal?

In the current case, it is posited therefore that there are three types of empirical events: *social event* $\boldsymbol{A_S}$ (goal achievement), *material event* $\boldsymbol{R_F}$ (technology action result), and *sociomaterial event* $\boldsymbol{R_F,A_S}$ (social goal achievement through technology interaction). Each of the three events (i.e. *social event* $\boldsymbol{A_S}$, *material event* $\boldsymbol{R_F}$, and *sociomaterial event* $\boldsymbol{R_F,A_S}$), are potential outcomes of affordance causal conjunctures. That is, all three are purported to be outcomes of some afforded phenomenon.

In terms of structure and logic of causal explanations, an observable *event* is caused by a *mechanism* enabled by a *structure*, subject to *contingent conditions* (Easton, 2010). The causal explanations will follow the format: *actual event* $\boldsymbol{E_1}$ observed as *empirical event* $\boldsymbol{E_1}$ is caused by *mechanism* $\boldsymbol{M_1}$ of *structure* $\boldsymbol{S_1}$ under specified *condition* $\boldsymbol{C_1}$ or alternatively *structure* $\boldsymbol{S_1}$ has *mechanism* $\boldsymbol{M_1}$, under specified *condition* $\boldsymbol{C_1}$ to cause *event* $\boldsymbol{E_1}$ similar to the example in Easton (2010, p. 122).

However, the contingent conditions implied in this instance are *structural conditions* (Sayer, 2010). That is, under *specified conditions* constraining and/or enabling the structure the mechanisms causing the event will be enabled or constrained. Furthermore, the "*structures and their associated mechanisms are ontologically decoupled from the events they produce*" (Tsang, 2014, p. 176). This implies that the causality of *event* $\boldsymbol{E_1}$ above is effectively: *mechanism* $\boldsymbol{M_1}$ *of structure* $\boldsymbol{S_1}$ under specified structural *conditions* $\boldsymbol{C_1}$ (Easton, 2010).

In the *causal explanation* diagrams below (see Figure 16), the *solid bold thick lines* represent the possible *causal explanations*, and the *dotted lines* represent possible *empirical accounts*. *Empirical accounts* may or may not faithfully reflect the underlying actual events, possibly due to *empirical* limitations.

5.4.2 *Causal explanans*

As noted elsewhere, the observable *social*, *material* or *sociomaterial* events could be caused by *social*, *material*, and/or *sociomaterial* conjunctures or possible combinations thereof (see Figure 16) (Tsang, 2014). The observed *social event* $\boldsymbol{A_S}$ (see Figure 16) may be caused by the *realisation* or *failures* of various *social*, *material*, and/or *sociomaterial* conjunctures and likewise the *empirical material event* $\boldsymbol{R_F}$, as well as the *sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$) and *vice versa* (see Figure 15 and Figure 16) (Easton, 2010; Tsang, 2014).

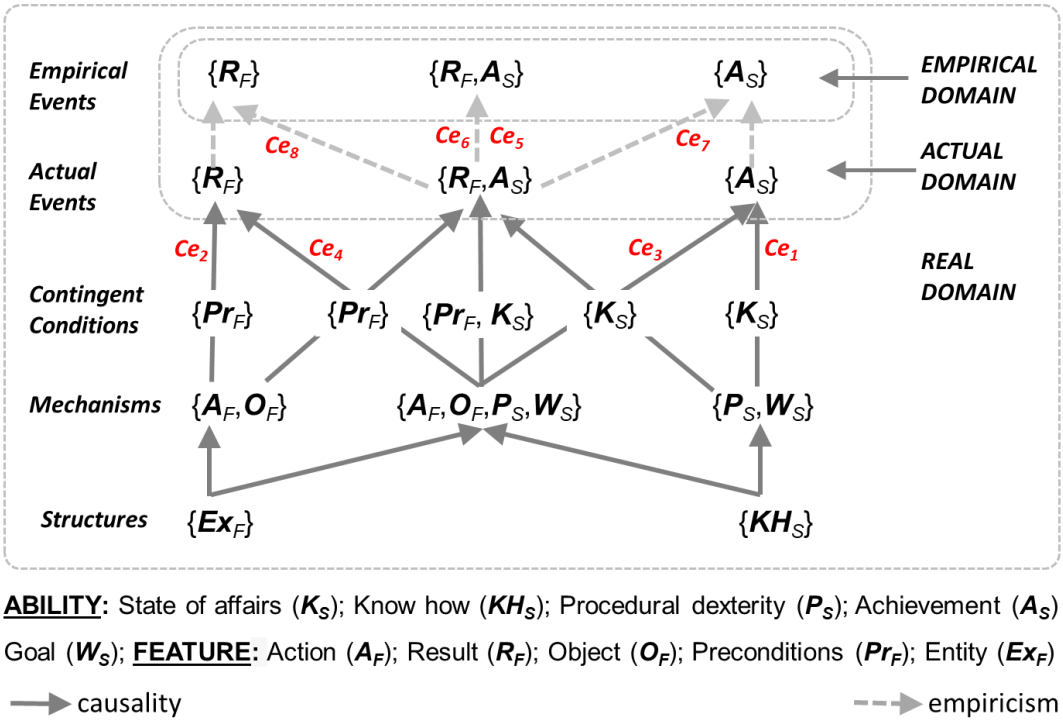


Figure 16 Retroduction of plausible causal explanations

The proposed causal explanations are plausible conjunctures or possible combinations thereof deemed to be capable of causing the observable *social*, *material*, or *sociomaterial* events. Furthermore, it is also conceded that the observable *social*, *material*, and/or *sociomaterial* events could be causal *misnomers*, *metaphors*, or *empirical* misinterpretations (Markus & Rowe, 2018). The following *causal explanations* can be retroduced from the theoretical re-descriptions of feature and ability outlined in the previous steps (see Figure 15 and Figure 16):

> $\boldsymbol{Ce_1}$**:** the *empirical social event* $\boldsymbol{A_S}$ is the observed actual *social event* $\boldsymbol{A_S}$, that is caused by social *mechanism* ($\boldsymbol{P_S,W_S}$) of the $\boldsymbol{KH_S}$ social *structure* under

specified K_S social *conditions*. These are pure social conjunctures without material technology contributions.

Ce_2: the *empirical material event* R_F, is the observed actual *material event* R_F, that is caused by *material mechanism* (A_F,O_F) of the Ex_F *material structure*, under specified Pr_F *material conditions*. These are pure *material* conjunctures without social agency contributions.

Ce_3: the *empirical social event* A_S is the observed actual *social event* A_S, that is caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified K_S social *conditions*.

Ce_4: the *empirical material event* R_F is the observed actual *material event* R_F, caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified Pr_F *material conditions*.

Ce_5: the *empirical sociomaterial event* (R_F,A_S), is the observed actual *sociomaterial event* (R_F,A_S) caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified *sociomaterial conditions* (Pr_F,K_S).

Ce_6: the *empirical sociomaterial event* (R_F,A_S), is the observed actual *sociomaterial event* (R_F,A_S), caused by incidental *sociomaterial* concurrence of causal explanation Ce_1 and Ce_2.

Ce_7: the *empirical social event* A_S, is the *empirical* misinterpretation of causal explanation Ce_5 and/or Ce_6 in favour of social causality.

Ce_8: the *empirical material event* R_F, is the *empirical* misinterpretation of causal explanation Ce_5 and/or Ce_6 in favour of material causality.

5.4.3 *Causal assumptions*

The following assumptions are deemed to be applicable to the context and scenarios of the retroduced set of, plausible event-causal explanations — *social* event-causal explanations (Ce_1, Ce_3, Ce_7); *material* event-causal explanations (Ce_2, Ce_4, Ce_8); and *sociomaterial* event-causal explanations (Ce_5, Ce_6) (Easton, 2010; Tsang, 2014):

(i) The ***actor-artefact-actor*** interactions are ***explicitly excluded*** among the cases. It is assumed the artefacts have *independent causal agency* and are capable of *independent interaction* with the social agency. Albeit, it is conceded that all the material entities are artificial and thus human-designed, created, and/or operated.

(ii) Affordances include instances of unprovoked technology afforded outcomes or instance where an automated artefact independently generate an outcome on behalf of the social actor physically unprovoked.

(iii) *Material* mechanism ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$) cannot independently cause *sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$), if it was to be observed to have caused such, it would probably be a case of empirical misinterpretations or experiential limitations (Markus & Rowe, 2018).

(iv) *Social* mechanism ($\boldsymbol{P_S,W_S}$) cannot independently cause *sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$), if it was to be observed to have caused such, it would probably be a case of empirical misinterpretations or experiential limitations (Markus & Rowe, 2018).

(v) *Sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$), can either be an emergent outcome of both social ($\boldsymbol{P_S,W_S}$) and material ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$) mechanism individually or as an outcome of the integrated *sociomaterial* mechanism ($\boldsymbol{A_F}$,$\boldsymbol{O_F,P_S,W_S}$).

(vi) *Sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$) may be caused by the integrated *sociomaterial* mechanism ($\boldsymbol{A_F}$,$\boldsymbol{O_F,P_S,W_S}$) but also through incidental *sociomaterial* concurrence of the *social event* $\boldsymbol{A_S}$ and *material event* $\boldsymbol{R_F}$ individually due to emergence (emergent causality) (Markus & Robey, 1988; Markus & Rowe, 2018).

(vii) *Sociomaterial event* ($\boldsymbol{R_F}$,$\boldsymbol{A_S}$) may empirically be observed as such, but also observed as *social event* $\boldsymbol{A_S}$, or *material event* $\boldsymbol{R_F}$, due to empirical misinterpretations or experiential limitations (i.e. causal misnomers or metaphors) (Markus & Rowe, 2018).

5.5 Empirical corroboration

Empirical corroboration (Wynn & Williams, 2012) or the c*omparison* between different theories and abstractions involves assessing the cogency of the identified or retroduced explanations (Raduescu & Vessey, 2009). The retroduced explanations need to be empirically corroborated or validated (Wynn & Williams, 2012). Alternatively, the least plausible causal mechanisms can also be eliminated, and thus leaving the most plausible causal explanations as to the possible candidate propositions (Bygstad et al., 2016; Wynn & Williams, 2012).

5.5.1 *Causal relevance*

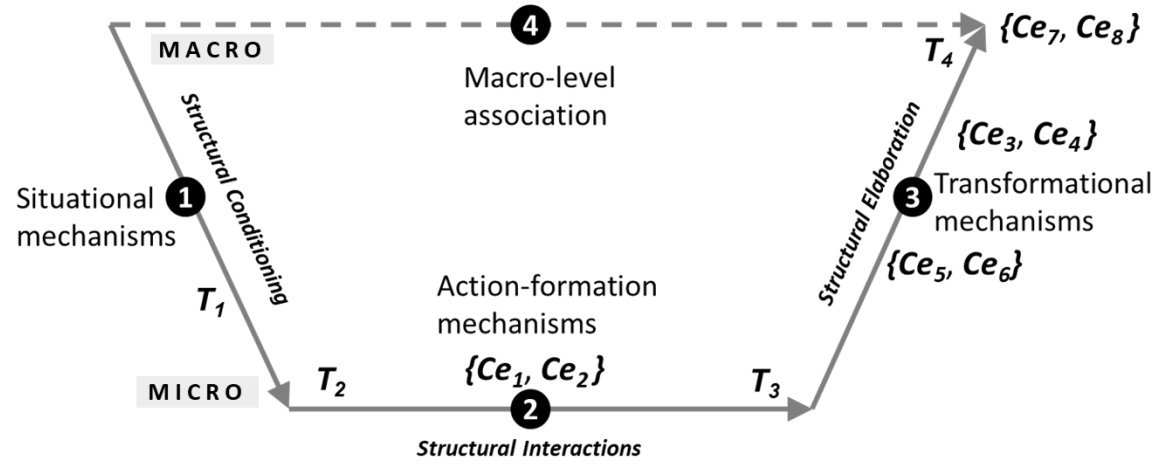
In terms of the mechanism-based view of social structure, the causal mechanisms involved: (a) *situational* mechanisms (macro-micro); (b) *action-formation* mechanisms (micro-micro); the (c) *transformational* mechanisms (micro-macro); and (d) *macro-level association* mechanisms (macro-macro) (Hedström & Ylikoski, 2010). The focus in the current case is the *action-formation* mechanisms (micro-micro) and the *transformational* mechanisms (micro-macro) (Hedström & Ylikoski, 2010).

The action-formation mechanisms (micro-micro) involve individual entity behaviour (Hedström & Ylikoski, 2010; Matsueda, 2017; Mayntz, 2004). However, the transformational mechanisms (micro-macro) involve not only the aggregate causality of the micro-micro action-formation mechanisms but a complex arrangement of structural conjunctures (Hedström & Ylikoski, 2010; Matsueda, 2017; Mayntz, 2004; Papachristos, 2018). For instance, Matsueda (2017) notes that apart from the macro-micro influence on the micro-micro and micro-macro, there are also macro-micro-macro influences in micro-macro transitions or transformational mechanisms.

The question, however, is what type of causal explanations qualify as relevant for affordance phenomena? In terms of speculative triangulation based on extant theory, the direct answer would be the micro-macro explanations (Hedström & Ylikoski, 2010; Matsueda, 2017; Mayntz, 2004). The challenge, however, is trying to explain the nature of such a micro-macro *transformational* mechanism or ‘micro-macro transitions’ (Matsueda, 2017). The problem with explaining the *micro-macro* transformational

mechanisms is that not only do they involve the cumulative *micro-micro* mechanisms, but also the *macro-micro-macro* influences as well (Matsueda, 2017).

The retroduced set of plausible causal explanations consist of eight explanations (hereafter simply referred to individually as — ***Ce1***, ***Ce2***, ***Ce3***, ***Ce4***, ***Ce5***, ***Ce6***, ***Ce7***, or ***Ce8***). Out if the eight explanations, three are *social* event (***Ce1***, ***Ce3***, ***Ce7***); three *material* events (***Ce2***, ***Ce4***, ***Ce8***); and two *sociomaterial* events (***Ce5***, ***Ce6***) causal explanations. Out of the eight plausible causal explanations two can be classified unambiguously as the micro-micro *action-formation* mechanisms — ***Ce1***, and ***Ce2***. The other six causal explanations — ***Ce3***, ***Ce4***, ***Ce5***, ***Ce6***, ***Ce7***, and ***Ce8***, may fall into either *action-formation* mechanisms and/or *transformational* mechanisms (see Figure 17).



LEGEND

FEATURE:	***ABILITY***:
Action (A_F)	State of affairs (K_S)
Result (R_F)	Know how (KH_S)
Object (O_F)	Performance (P_S)
Entity (Ex_F)	Achievement (A_S)
Preconditions (Pr_F)	Motivation (W_S)

Event	Mechanism	Structure	Conditions
Ce_1 (A_S)	(P_S,W_S)	(KH_S)	(K_S)
Ce_2 (R_F)	(A_P,O_P)	(Ex_F)	(Pr_F)
Ce_3 (A_S)	(A_P,O_P,P_S,W_S)	(Ex_F ,KH_S)	(K_S)
Ce_4 (R_F)	(A_P,O_P,P_S,W_S)	(Ex_F ,KH_S)	(Pr_F)
Ce_5 (R_P, A_S)	(A_P,O_P,P_S,W_S)	(Ex_F ,KH_S)	(Pr_P,K_S)
Ce_6 (R_P, A_S)	(A_P,O_P) & (P_S,W_S)	(Ex_F) & (KH_S)	(Pr_F) & (K_S)
Ce_7 (A_S)	(A_P,O_P,P_S,W_S) or (A_P,O_P) & (P_S,W_S)	(Ex_F ,KH_S) or (Ex_F) & (KH_S)	(Pr_P,K_S) or (Pr_F) & (K_S)
Ce_8 (R_F)	(A_P,O_P,P_S,W_S) or (A_P,O_P) & (P_S,W_S)	(Ex_F ,KH_S) or (Ex_F) & (KH_S)	(Pr_P,K_S) or (Pr_F) & (K_S)

Figure 17 Retroduced plausible causal explanations

In terms of affordances, the likely plausible causal explanations would be those explaining causality of goal-directed actor afforded concrete outcomes (i.e. events), which involves actor-artefact interactions (Volkoff & Strong, 2013). That is, the criteria

for assessing the cogency of the retroduced causal explanation need to account or include the nature of the relation between the affording artefact and the afforded actor. This is because in order to satisfy the affordance phenomenon, the artefact need to afford something to the actor, and the actor likewise need to be afforded something by the artefact. Affordances are relational action potentials between goal-directed actors and artefacts (Volkoff & Strong, 2013). Thus, the cogency of the causal explanations corresponding to affordances necessarily should involve (a) goal-directed actor afforded *concrete outcome*; (b) *actor-artefact relation* or interaction (Volkoff & Strong, 2013).

In terms of the typical actor-artefact relation or interaction anticipated by the information systems (IS) *elementary interaction loop* (Goldkuhl et al., 2004). Ordinarily, the plausibility of causal explanation $\boldsymbol{Ce_1}$ and $\boldsymbol{Ce_2}$ would be in doubt due to the actor-artefact relation or interaction criteria. This is because whilst either $\boldsymbol{Ce_1}$ and $\boldsymbol{Ce_2}$ may explain the causality of an afforded *outcome* to a goal-directed actor, however, both do not directly involve actor-artefact relation or interaction (Volkoff & Strong, 2013). This is because in $\boldsymbol{Ce_1}$ the social event $\boldsymbol{A_S}$ is generated independently and exclusively by the social mechanisms and related conjunctures apart from the material technology involvement. Likewise, the material event $\boldsymbol{R_F}$, in the causal explanation $\boldsymbol{Ce_2}$, it is generated independently and exclusively by the material mechanisms and related conjuncture without any social interactional involvement.

However, due to the advances in actor-artefact interactions which include the spatiotemporal dimensions in e*xperiential* computing, such explanations (i.e. $\boldsymbol{Ce_1}$ and $\boldsymbol{Ce_2}$) have become potentially plausible (Yoo, 2010). For instance, in the case of the information systems (IS) *elementary interaction loop* the interaction mainly involves physical actor-artefact dimension (Goldkuhl et al., 2004; Yoo, 2010). However, in the case of digital technologies, both the actor-artefact and the spatiotemporal dimensions are involved as well as possible combinations thereof (Yoo, 2010). Furthermore, with e*xperiential* computing the dimensional colocation of the actor and artefact interactions is irrelevant. This is because an unrelated spatiotemporal occurrence could elicit a physical technology response, even without social actor intent (Yoo, 2010).

In the current case, for instance, the imagined social actor puts the smartphone inside pocket during an ongoing phone call. The smartphone proximity sensor, then

automatically switches off the screen to avoid unintentional haptic input data. Another example includes the oculesic sensor which switches the screen on and off when it senses that the social actor is not watching or reading from the screen, and automatically wakes when it senses oculesic interaction. These are just a few examples, of causal explanation ***Ce₁*** plausibility and probably ***Ce₂*** as well as the rest of the retroduced explanations.

5.5.2 *Causal mechanisms*

In terms of the retroduced set of plausible causal explanations, two types of mechanisms or causal explanations (see Figure 18) can be deduced based on their event or outcome causal interactions: (a) *indirect mechanisms*; (b) *direct mechanisms*. Indirect mechanisms or '*indirect* causality' involve *asynchronous* indirect actor-artefact interactions that lead to concrete outcomes. Direct mechanisms or '*mechanism* causality' on the other hand involve *synchronous* direct actor-artefact involvement and interaction in the generation of concrete outcomes.

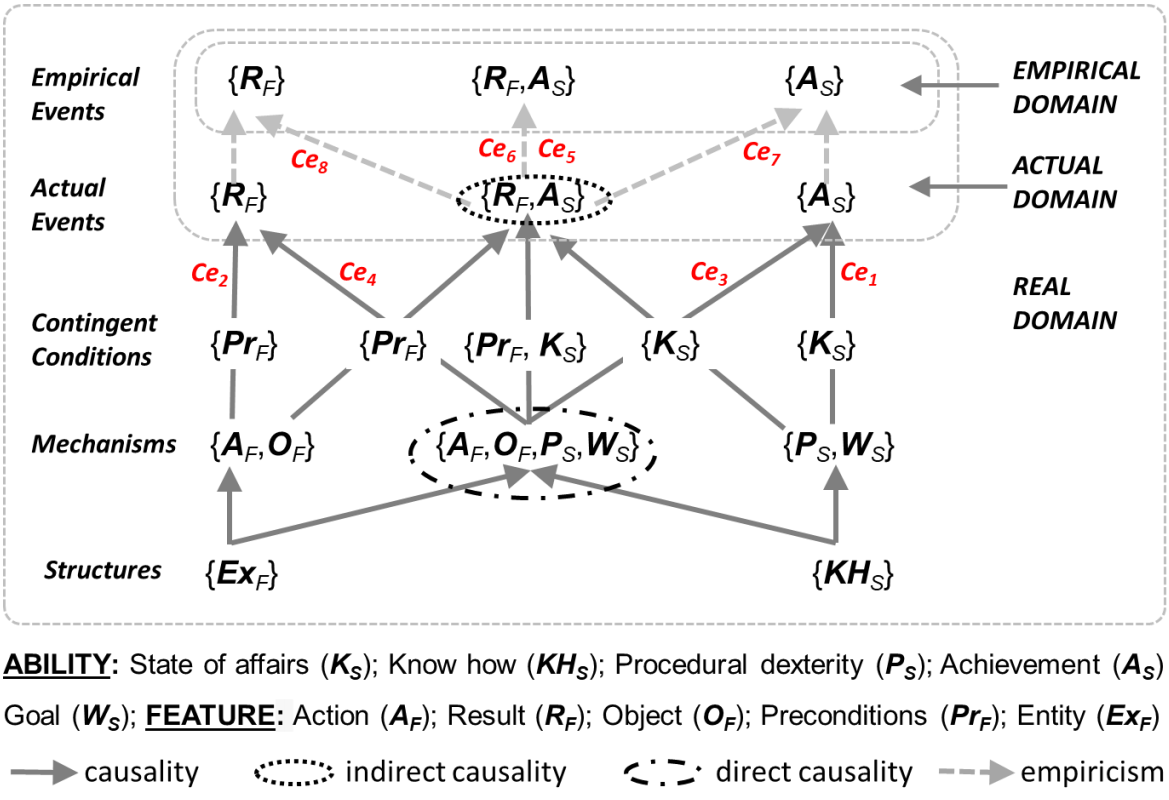


Figure 18 Direct and indirect affordance plausible causal explanations

The *indirect mechanisms* involve *asynchronous indirect* actor-artefact interactions. outcome or Either party in the actor-artefact interaction (i.e. social actor or artefact) individually and/or independently generates events which are also independently responded to by the other interacting party in the interaction. That is, the material event R_F (artefact result) can be used by the social actor to accomplish an achievement A_S or the social event A_S is input into the material mechanism to accomplish a material event R_F. Alternatively, both social event A_S and material event R_F constitute an observed emergent *sociomaterial event* (R_F,A_S).

The causal explanations associated with the *indirect mechanism* causal relations are causal explanation Ce_6, Ce_7, and Ce_8. That is when causal explanation Ce_1 and Ce_2 are providentially concurrent to cause the emergence of causal explanation Ce_6, and when causal explanation Ce_5 and the emergence of causal explanation Ce_6 is misinterpreted as causal explanations Ce_7, and Ce_8.

In the *direct mechanism*, both social and material structural conjunctures are actively involved in the generative causation of events. The *direct mechanism* involves *synchronous* actor-artefact interactions. Thus, the events are emergent outcomes of the structural interactions between the social and the material, resulting in an integrated *sociomaterial* causal mechanism (A_F,O_F,P_S,W_S).

The causal explanations associated with *direct mechanism*, are causal explanation Ce_3, Ce_4, and Ce_5. All three causal explanations involve the integrated *sociomaterial* causal mechanism (A_F,O_F,P_S,W_S), emerging from the actor-artefact interaction. Furthermore, unlike the *indirect mechanism* or indirect causality explanations, the causal explanation Ce_3, Ce_4, and Ce_5 do unambiguously conform to the affordance actor-artefact relation criteria (Volkoff & Strong, 2013).

5.5.3 *Indirect mechanisms*

The indirect mechanism actor-artefact relation involves event-level *asynchronous* (e.g. “postal service”) interactions between the actors and artefacts. Either party in the actor-artefact interaction (i.e. social actor or artefact) individually and/or independently generates events which are responded to by the other interacting party in the interaction. The *event-causal relation* can be explained through causal explanation

Ce₇, and ***Ce₈*** in the context of causal explanation ***Ce₆*** and causal explanation ***Ce₆*** as constitutively explained by causal explanation ***Ce₁*** and ***Ce₂***. For instance, the causal explanation ***Ce₁*** and ***Ce₂***, unless taken together by some providential mechanism cannot on their own, individually cannot account for affordances.

However, when taken together, as it is often the case in practice, both causal explanation ***Ce₁*** and ***Ce₂*** can collectively account for affordances, as constitutive causal explanations of causal explanation ***Ce₆***. That is, the ***Ce₁*** social event ***A_S*** and ***Ce₂*** material event ***R_F*** together constitute an emergent social goal-achieving *sociomaterial event* (***R_F***,***A_S***). This is because to satisfy the affordance phenomenon, the artefact needs to afford something to the actor, and the actor likewise needs to be afforded something by the artefact.

By way of an analogy from the case, suppose a social actor has time knowledge structure ***KH_S***, and uses some time interpreting mechanism (***P_S,W_S***) to realise a need for time ***A_S*** at the current moment ***K_S***. The smartphone ***Ex_F*** also has its 'own' inbuilt digital clock or time mechanism (***A_F***,***O_F***) which independently displays (causes) time events ***R_F*** under normal operating conditions ***Pr_F***. The causality of the smartphone ***Ex_F*** material events ***R_F*** would be explained with the ***Ce₂*** causal explanations or the ***Ce₈*** biased material event misinterpretation. The social actor time-seeking phenomenon, on the other hand, would be explained as a *social event* ***A_S*** of causal explanation ***Ce₁***, or the ***Ce₇*** biased social event misinterpretation.

However, were the social actor to glance over the smartphone ***Ex_F***, to determine the time ***W_S*** (social goal), at the current moment ***K_S*** (state of affairs); and the time displayed ***R_F*** (material result) under normal operating conditions ***Pr_F*** of the smartphone ***Ex_F*** (material structure), were to display 14H00 ***R_F***, at that glancing moment ***K_S***. The social actor having the time interpretation dexterity ***P_S*** would achieve the goal ***W_S*** of determining the current ***K_S*** local time ***A_S*** to be 14H00. The emergent ***Ce₁*** and ***Ce₂*** affordance causal phenomena would correctly be interpreted as ***Ce₆*** causal explanation.

However, supposing the goal of determining the time ***W_S*** is not just local time but some social time such as *lunchtime* or *breakfast-time*, *night-time, sleep-time*, or any such abstract social conceptions of time. The interpretation of the emergent ***Ce₁*** and ***Ce₂***

affordance causal phenomena might be biased towards a social conception of the 14H00 local time A_S to be instead *lunchtime* or any other social conception of time as needed. That is, in terms of the scenario the smartphone would have afforded *lunchtime* to the social actor, instead of the digital 14H00 time. This would be a case of Ce_7 causal explanation (the biased misinterpretation of the social event).

The logic is the same as the Ce_8 biased material event misinterpretation. The absence of specific social goals in context would render the emergent Ce_1 and Ce_2 causal phenomena to be *empirically* biased towards material causality (i.e. material action potentiality). This is the case of affordance features or feature-based affordances (Lim & Kim, 2009). This scenario would be a case of causal explanation Ce_8 which may be viewed as a biased *empirical* misinterpretation of causal explanation Ce_5 and/or Ce_6 in favour of material causality.

5.5.4 *Direct mechanisms*

In terms of the *direct mechanism* or simply mechanism causality, the events generated are an outcome of the interaction between the social and material conjunctures. The causal explanation Ce_3, Ce_4, and Ce_5 are exemplary expressions of mechanism causality, wherein both the *material* mechanism (A_F,O_F) and *social* mechanism (P_S,W_S) are involved in the generation of events. Furthermore, in terms of the affordance criteria, the causal explanation Ce_3, Ce_4, and Ce_5 are plausible affordance explanations (Volkoff & Strong, 2013). This is because of these causal explanations involve some goal-directed social agency and an action affording material artefact (Volkoff & Strong, 2013).

The *direct mechanism* causality is an outcome of the integrated *sociomaterial* mechanism (A_F,O_F,P_S,W_S), derived from the *material* (A_F,O_F) and *social* (P_S,W_S) mechanisms. As noted in the retroduction assumptions, the integrated *sociomaterial* mechanism (A_F,O_F,P_S,W_S) can generate *sociomaterial event* (R_F,A_S) under specified *sociomaterial conditions* (Pr_F,K_S), *social event* A_S under specified K_S social *conditions*, and *material event* R_F, under specified Pr_F *material conditions*.

In the current case the integrated *sociomaterial* mechanism (A_F,O_F,P_S,W_S) embody the any of the *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal*

communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). For instance, a text-based communicative interaction would involve the social mechanism (***P*****S,*****W*****S**) — text inputting procedural dexterity (e.g. typing) ***P*****S,** the goal ***W*****S** (reasonings about text syntax, semantics, and content); and the material mechanism (***A*****F**,***O*****F**) — text or character processing action ***A*****F**, and character inputting object ***O*****F** (i.e. input device, e.g. keyboard, touchscreen, scanner, etc.) (see Table 5).

Table 5 Smartphone communicative interactions

Interaction	Feature	Mechanism Description
Chronemic	*Power Key*	Press the power key to turn off the touchscreen or Press-hold for 2-3 seconds the power key to view device turn on/off options
Proxemic	*Proximity sensor*	Proximity-based touchscreen and touch functionality switch-off during calls.
Kinesic	*Gesture Control*	Use hand gestures to hover over or swipe over the touch screen to navigate to various device functionality
Haptics	*Touch screen*	Tab or touch the touch screen to navigate to various device functionality.
Oculesic	*Smart Stay*	Keeps the smartphone screen on while the social actor is watching the screen.
Vocalic/ Verbal	*Voice Typing*	Voice-based text typing enables users to speak rather than type their text entries.
Textual	On-screen keyboard	Enter or type text using the on-screen keyboard.

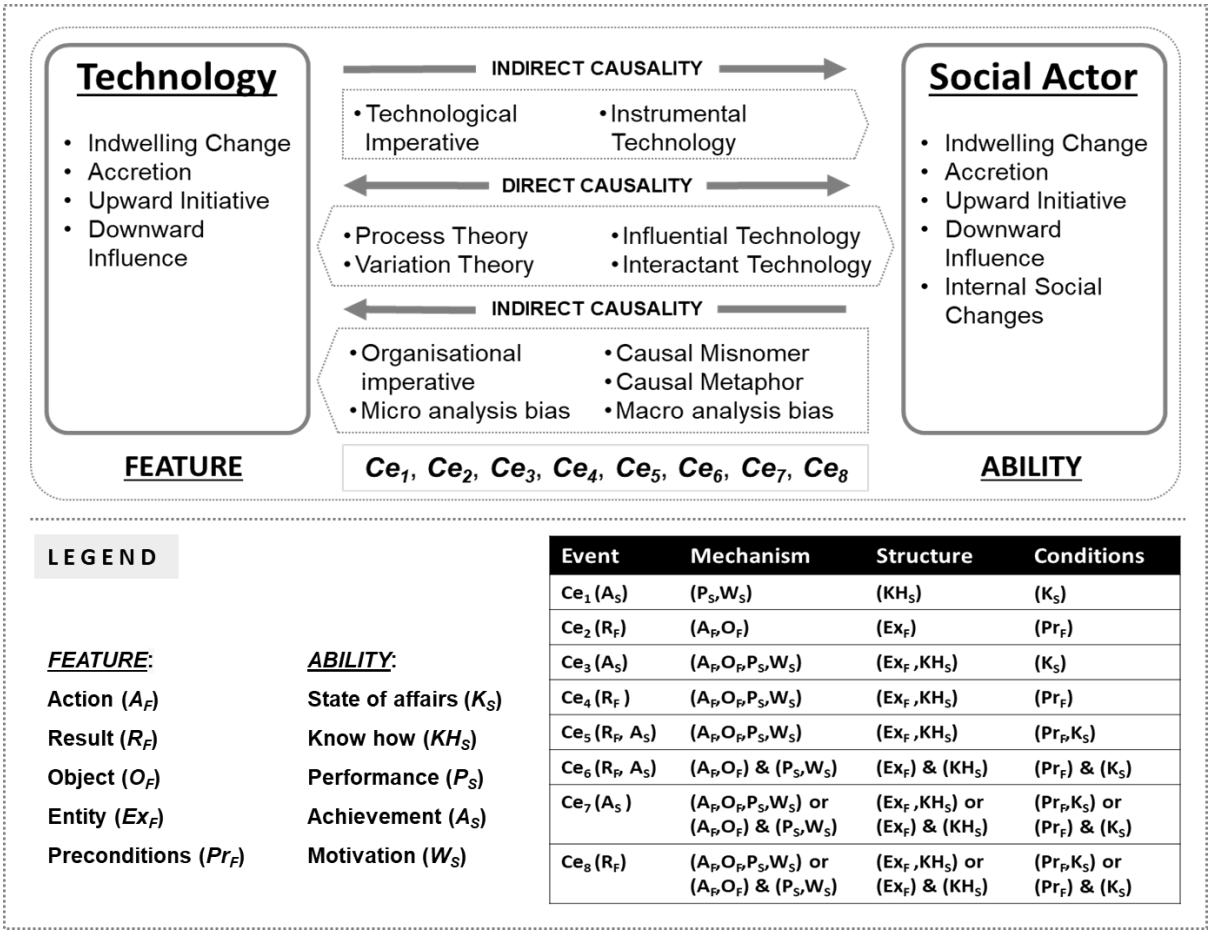
Likewise, with the other modes of communicative interaction (i.e. *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal*). The content and configuration of the *sociomaterial* mechanism (***A*****F**,***O*****F,*****P*****S,*****W*****S**) are determined by the modal context of interaction which may be any of *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal* communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). In the current case, the studied smartphone device had an oculesic function “Smart Stay”, which ensures that the smartphone screen does not switch off while the social actor is watching the screen (Samsung, 2019). On the contrary, to avoid unintended on-screen typing during calls or inside pocket, the

“Proximity sensor” (i.e. proxemic interaction function), switches off the touchscreen and touch functionality (see Table 5) (Samsung, 2019).

5.5.5 *Causal plausibility*

The nature of affordance causal mechanisms varies from context to context (Davis & Chouinard, 2017). In the diagram (see Figure 19) and Table 6, the various theories corroborating the retroduced set of plausible causal explanations are mapped to the causal explanations in the context of the actor-artefact interactions. For instance, there could be an actual *causal mechanism* (i.e. ontologically real mechanism), either *material* or *social* causality responsible for the observed phenomenon (Markus & Robey, 1988; Markus & Rowe, 2018). The causal mechanism could also be due to the presence of certain necessary and sufficient antecedents (i.e. *variation theory*) or due to a sequence of necessary occurrences which may or may not be causatively sufficient (i.e. *process theory*) (Markus & Robey, 1988). The v*ariation theory* causal propositions corroborate causal explanations ***Ce₁***, ***Ce₂***, ***Ce₃***, ***Ce₄***, ***Ce₅***, and ***Ce₆***; whilst the *process theory* causal propositions corroborate causal explanations ***Ce₁***, ***Ce₂***, ***Ce₆***, ***Ce₇***, and ***Ce₈*** (Markus & Robey, 1988).

The trajectory of causation could also be from the *material* artefact to *social* actors (*technological imperative*) — corroborating causal explanation ***Ce₂***); or *social* to *the material* (*organisational imperative*) (i.e. ***Ce₁***) (Markus & Robey, 1988; Markus & Rowe, 2018). The trajectory of causation could also be bidirectional (*emergent* causality), (i.e. corroborating causal explanation ***Ce₃***, ***Ce₄***, ***Ce₅***, and ***Ce₆***) (Markus & Robey, 1988; Markus & Rowe, 2018). Furthermore, the trajectory of causation could also involve multi-level natural system strata, that is *inter-level* causation — from high to low (*downward influence*); low to high (*upward initiative*); or back-and-forth inter-level *self-organising* (i.e. ***Ce₁***, ***Ce₂***, and ***Ce₆***) (Markus & Rowe, 2018). The trajectory can also be *intra-level* (*intra-level* causation) — causation by natural growth (*accretion*); or any internal reconfiguration (*indwelling change*), or loss, or addition of new elements (i.e. ideas, resources, etc.) without any external influence (i.e. ***Ce₁***, ***Ce₂***, and ***Ce₆***) (Markus & Rowe, 2018).



Event	Mechanism	Structure	Conditions
$Ce_1 (A_S)$	(P_S,W_S)	(KH_S)	(K_S)
$Ce_2 (R_F)$	(A_P,O_P)	(Ex_F)	(Pr_F)
$Ce_3 (A_S)$	(A_P,O_P,P_S,W_S)	(Ex_F,KH_S)	(K_S)
$Ce_4 (R_F)$	(A_P,O_P,P_S,W_S)	(Ex_F,KH_S)	(Pr_F)
$Ce_5 (R_P, A_S)$	(A_P,O_P,P_S,W_S)	(Ex_F,KH_S)	(Pr_P,K_S)
$Ce_6 (R_P, A_S)$	(A_P,O_P) & (P_S,W_S)	(Ex_F) & (KH_S)	(Pr_F) & (K_S)
$Ce_7 (A_S)$	(A_P,O_P,P_S,W_S) or (A_P,O_P) & (P_S,W_S)	(Ex_F,KH_S) or (Ex_F) & (KH_S)	(Pr_P,K_S) or (Pr_F) & (K_S)
$Ce_8 (R_F)$	(A_P,O_P,P_S,W_S) or (A_P,O_P) & (P_S,W_S)	(Ex_F,KH_S) or (Ex_F) & (KH_S)	(Pr_P,K_S) or (Pr_F) & (K_S)

Figure 19 Theoretical plausibility of retroduced causal mechanisms

(adapted Markus & Robey, 1988; Markus & Rowe, 2018)

Furthermore, the observed purported causal phenomena might be a case of *indirect causality* — corroborating ***Ce1***, ***Ce2***, and ***Ce6*** (Markus & Rowe, 2018). That is, the purported causality might be due to causally unrelated associations among precedent temporal conditions (i.e. ***Ce6***) (Markus & Rowe, 2018). The causality could also be a convenient *metaphor* for such causally unrelated associations or simply an ontological *misnomer* — mere human belief about meanings enacted in social interactions — corroborating ***Ce7*** and ***Ce8*** (Markus & Rowe, 2018). The role of technology could also be overestimated (i.e. ***Ce8***) or underestimated (i.e. ***Ce7***), depending on the purported role played by the technology artefact in such causal relation (Markus & Rowe, 2018). This is because the technology could be a mere *interactant* (i.e. ***Ce7***), in the interaction of a social *instrument* (i.e. ***Ce1***, ***Ce3***, ***Ce4***, ***Ce5***, ***Ce6*** and ***Ce7***) or an autonomous *influencer* (i.e. ***Ce8*** and ***Ce2***) (Markus & Rowe, 2018).

Table 6 Theoretical corroboration of causal explanations

(adapted Markus & Robey, 1988; Markus & Rowe, 2018)

CE	Event	Type	Causality	Theoretical Foundation
Ce_1	A_S	***S***	Indirect (*asynchronous)*	variation theory, process theory, organisational imperative, inter-level causation, intra-level causation, indirect causality, instrument technology, social change, analysis bias
Ce_2	R_F	***M***	Indirect (*asynchronous)*	variation theory, process theory, technological imperative, inter-level causation, intra-level causation, indirect causality, influencer technology
Ce_3	A_S	***S***	Direct *(synchronous)*	variation theory, emergent causality, instrument technology
Ce_4	R_F	***M***	Direct *(synchronous)*	variation theory, emergent causality, instrument technology
Ce_5	R_F,A_S	***SM***	Direct *(synchronous)*	variation theory, emergent causality, instrument technology
Ce_6	R_F,A_S	***SM***	Indirect (*asynchronous)*	variation theory, process theory, emergent causality, inter-level causation, intra-level causation, indirect causality, instrument technology
Ce_7	A_S	***S***	Indirect (*asynchronous)*	process theory, causal metaphor, a causal misnomer, interactant technology, instrument technology, social change, analysis bias
Ce_8	R_F	***M***	Indirect (*asynchronous)*	process theory, causal metaphor, a causal misnomer, influencer technology, social change, analysis bias

Achievement (***A_S***) Result (***R_F***) Sociomaterial (***SM***) Material (***M***) Social (***S***)

As an *interactant,* technology has no volition but is subject to human intentional actions (i.e. ***Ce_7***) (Markus & Rowe, 2018). Technology as an *influencer*, has some autonomous operational capacity with limited human intervention (i.e. ***Ce_8*** and ***Ce_2***) (Markus & Robey, 1988; Markus & Rowe, 2018). In the case of technology as an *instrument,* the causation is typically *bidirectional* or *emergent* where technology is used as an instrument for attaining social goals (i.e. ***Ce_1***, ***Ce_3***, ***Ce_4***, ***Ce_5***, ***Ce_6***, and ***Ce_7***) (Markus &

Robey, 1988; Markus & Rowe, 2018). The causation could also be due to *internal* changes within the social actors themselves related and/or unrelated to the material (e.g. social actors acquiring or losing certain attributes) (i.e. ***Ce₁***, ***Ce₇***, and ***Ce₈***) (Markus & Robey, 1988; Markus & Rowe, 2018).

In the case of a social actor associated causation, the causal explanation could also be influenced by the *biases of the observer's* chosen focus of analysis (i.e. ***Ce₁***, ***Ce₇***, and ***Ce₈***) (Markus & Robey, 1988). For instance, if the analysis is conducted at the individual (*micro-level of analysis*) the outcomes might be different to when the analysis is conducted at the organisational or *macro level of analysis* (Markus & Robey, 1988). This implies that even the assigning of the origin of causality could be problematic still if the level of analysis is not appropriate for the causal explanations advanced (Markus & Rowe, 2018).

5.5.6 *Causal considerations*

Other issues that could conflate the empirical causal anomalies include the social actor stances concerning the artefact involved (Vermaas et al., 2013). For instance, a key feature of any successful sociomaterial engagement is the ability of the social actors to accurately predict the behaviour of the material artefacts. For an example, in order to be able to successfully drive car, a car driver needs to be able to predict or anticipate the "behaviour" or how the car would respond to the inputs from the driver. Similarly, with technology artefacts and related devices, the artefact-social interaction behaviour prediction, needs to be accurate for a successful engagement. The accuracy of this artefact-social behaviour prediction depends on the artefact *symbolic expressions* (Cheikh-Ammar, 2018; Markus & Silver, 2008) and the *design stances* of the social actors (Vermaas et al., 2013). Design stances are artefact social perceptions (Vermaas et al., 2013). Symbolic expressions are *communicative possibilities* of artefacts (Markus & Silver, 2008).

The social actors can perceive material artefacts from different perspectives or design stances (Vermaas et al., 2013). Dennett (cited in Vermaas et al., 2013) describes three stances — *physical* stance, the *design* stance, and the *intentional* stance (Vermaas et al., 2013). The *physical stance* is the perspective of predicting the behaviour of artefacts by appealing upon their material physical properties. The *intentional stance*

(Vermaas et al., 2013) on the other hand is by appeal upon the artefact performative agency or its “spirit”— perceiving the artefact to be independently capable of behaving as intendedly designed or having its own “spirit” (Cheikh-Ammar, 2018; DeSanctis & Poole, 1994; Markus & Silver, 2008).

The *design stance* (Vermaas et al., 2013) is by appeal upon the functional feature composition of the artefact or the *structural features* of the artefact (Cheikh-Ammar, 2018; DeSanctis & Poole, 1994; Markus & Silver, 2008). The *design stance* includes the ‘*as-used-by-design’ (intentional designer stance)* and the ‘*as-usefully-used’* (*teleological design stance*) views (Vermaas et al., 2013). The *intentional designer stance* is the use of an artefact as *designedly* intended, whilst the *teleological design stance* is the ‘*as-usefully-used’* view (Vermaas et al., 2013). Typically, *tools* are the *as-used-by-design* artefacts (*intentional designer stance*), whilst *instruments* are the *as-usefully-used* artefacts (*teleological design stance*) (Vermaas et al., 2013).

Hence, the way an artefact is viewed by its users, whether as a *tool* (*intentional designer stance*); *instrument* (*teleological design stance*); *physical artefact* (*physical stance*); or *purposive agent* (*intentional stance*), may be, a function of the artefact’s s*ymbolic expressions* and may determine how it will be used and consequently the affordances that can be perceived from the artefact (Cheikh-Ammar, 2018; Markus & Silver, 2008; Vermaas et al., 2013).

5.6 Conclusion

In the current case of a smartphone device, the imagined *social actor* interacts with the technology artefact in routine lifeworld use case *setting* through situated *chronemic*, *proxemic*, *kinesic*, o*culesic*, v*ocalic*, *textual*, and *verbal* communicative interactions (Carlsson, 2009; Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011; Wang et al., 2016). The interactions lead to concrete outcomes or events in critical realist context (Volkoff & Strong, 2013). In terms of the critical realist causal reasoning, events are generated by *mechanisms* of *entities* and/or *structural conjunctures* but also through *mechanism interactions* (Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Sayer, 2010; Wynn & Williams, 2012).

5.6.1 *Affordance causal logic*

In the actor-artefact interactional relations, three types of afforded events are possible, the *social*, *material*, and *sociomaterial* events. That is, in terms of the actor-artefact interactional relations, *social events* can potentially emanate from *social conjunctures*, and *material events* from *material conjunctures*, but also *sociomaterial events* from *social* and *material mechanism interactions* (Easton, 2010; Mingers et al., 2013; Mingers & Standing, 2017; Sayer, 2010; Wynn & Williams, 2012). The causality of such events can be explained through the critical realist causal explanations (Easton, 2010; Tsang, 2014).

The logic of causal explanations follows the format: *actual event* $\boldsymbol{E_1}$ observed as *empirical event* $\boldsymbol{E_1}$ is caused by *mechanism* $\boldsymbol{M_1}$ of *structure* $\boldsymbol{S_1}$ under specified *condition* $\boldsymbol{C_1}$ or alternatively *structure* $\boldsymbol{S_1}$ has *mechanism* $\boldsymbol{M_1}$, that causes *actual event* $\boldsymbol{E_1}$ under specified *condition* $\boldsymbol{C_1}$ as follows (Easton, 2010).

> **Ce_1:** the *empirical social event* $\boldsymbol{A_S}$ is the observed actual *social event* $\boldsymbol{A_S}$, that is caused by social *mechanism* ($\boldsymbol{P_S,W_S}$) of the $\boldsymbol{KH_S}$ social *structure* under specified $\boldsymbol{K_S}$ social *conditions*. These are pure social conjunctures without material technology contributions.
>
> **Ce_2:** the *empirical material event* $\boldsymbol{R_F}$, is the observed actual *material event* $\boldsymbol{R_F}$, that is caused by *material mechanism* ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$) of the $\boldsymbol{Ex_F}$ *material structure*,

under specified Pr_F *material conditions*. These are pure *material* conjunctures without social agency contributions.

Ce_3: the *empirical social event* A_S is the observed actual *social event* A_S, that is caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified K_S social *conditions*.

Ce_4: the *empirical material event* R_F is the observed actual *material event* R_F, caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified Pr_F *material conditions*.

Ce_5: the *empirical sociomaterial event* (R_F,A_S), is the observed actual *sociomaterial event* (R_F,A_S) caused by the *sociomaterial* structural *mechanism* (A_F,O_F,P_S,W_S) emerging from the *material structure* Ex_F *and* the social *structure* KH_S under specified *sociomaterial conditions* (Pr_F,K_S).

Ce_6: the *empirical sociomaterial event* (R_F,A_S), is the observed actual *sociomaterial event* (R_F,A_S), caused by incidental *sociomaterial* concurrence of causal explanation Ce_1 and Ce_2.

Ce_7: the *empirical social event* A_S, is the *empirical* misinterpretation of causal explanation Ce_5 and/or Ce_6 in favour of social causality.

Ce_8: the *empirical material event* R_F, is the *empirical* misinterpretation of causal explanation Ce_5 and/or Ce_6 in favour of material causality.

5.6.2 *Affordance causal mechanisms*

The retroduced causal explanations seek to account for both actual and observable empirical events as well as possible empirical misinterpretations of actual events. For instance, some material events may be misinterpreted as social events and vice versa (Markus & Robey, 1988; Markus & Rowe, 2018). Also, some sociomaterial events could be misinterpreted as either social or material events (Markus & Robey, 1988; Markus & Rowe, 2018). This is because empirical events can manifest as distinctly social or material events but also as sociomaterial events (i.e. the observed integrated

manifestation of the social and the material events). Thus, it is deduced that event causality can be due to *indirect mechanisms,* and/or *direct mechanisms*.

The *indirect mechanisms* involve *asynchronous indirect* actor-artefact interactions. outcome or Either party in the actor-artefact interaction (i.e. social actor or artefact) individually and/or independently generates events which are also independently responded to by the other interacting party in the interaction. That is, the material event R_F (artefact result) can be used by the social actor to accomplish an achievement A_S or the social event A_S is input into the material mechanism to accomplish a material event R_F. Alternatively, both social event A_S and material event R_F constitute an observed emergent *sociomaterial event* (R_F,A_S).

The causal explanations associated with the *indirect mechanism* causal relations are causal explanation Ce_6, Ce_7, and Ce_8. That is when causal explanation Ce_1 and Ce_2 are providentially concurrent to cause the emergence of causal explanation Ce_6, and when causal explanation Ce_5 and the emergence of causal explanation Ce_6 is misinterpreted as causal explanations Ce_7, and Ce_8.

In the *direct mechanism*, both social and material structural conjunctures are actively involved in the generative causation of events. The *direct mechanism* involves *synchronous* actor-artefact interactions. Thus, the events are emergent outcomes of the structural interactions between the social and the material, resulting in an integrated *sociomaterial* causal mechanism (A_F,O_F,P_S,W_S).

The causal explanations associated with *direct mechanism*, are causal explanation Ce_3, Ce_4, and Ce_5. All three causal explanations involve the integrated *sociomaterial* causal mechanism (A_F,O_F,P_S,W_S), emerging from the actor-artefact interaction. Furthermore, unlike the *indirect mechanism* or indirect causality explanations, the causal explanation Ce_3, Ce_4, and Ce_5 do unambiguously conform to the affordance actor-artefact relation criteria (Volkoff & Strong, 2013).

5.6.3 *Affordance revised formalism*

In terms of structure and logic of causal explanations, an observable *event* is caused by a *mechanism* enabled by a *structure*, subject to *contingent conditions* (Easton,

2010, p. 122). However, affordances are also generative mechanisms capable of generating events or *concrete outcomes* (Bygstad et al., 2016; Volkoff & Strong, 2013). In terms of the critical realist logic, affordances are implied in the causal explanations of events as conditional event causation potentialities (Bygstad et al., 2016; Volkoff & Strong, 2013). It is proposed therefore that, as a conditional event causing potentialities, the descriptions of affordances need to explicitly describe their event causing conditions. Hence it is proposed that the conditionality of afforded actions, in the affordance expression be reviewed and formula [Aff1] to be replaced with the formula [Aff1.1] below (Chemero, 2003; Şahin et al., 2007):

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

> ***where affords*-ϕ** refers to the combined *actor-artefact mechanism* or sociomaterial mechanism ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$,$\boldsymbol{P_S}$,$\boldsymbol{W_S}$);
>
> ***where feature*** refers to the *conditional-causal-structure* of component technology *entity* $\boldsymbol{Ex_F}$ (*structure*), with its contingent conditionality $\boldsymbol{Pr_F}$, i.e. ($\boldsymbol{Ex_F}$, $\boldsymbol{Pr_F}$);
>
> ***where ability*** refers to the *conditional-causal-structure* of social actor know how $\boldsymbol{KH_S}$ (*structure*), with its contingent conditionality $\boldsymbol{K_S}$, i.e. ($\boldsymbol{KH_S}$,$\boldsymbol{K_S}$);
>
> ***and thence***;

affordance = ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$,$\boldsymbol{P_S}$,$\boldsymbol{W_S}$) (($\boldsymbol{Ex_F}$, $\boldsymbol{Pr_F}$), ($\boldsymbol{KH_S}$,$\boldsymbol{K_S}$)) [Aff1.1]

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS

In this section, the conclusions to the explanatory critical realist exploration, of the plausible causal mechanisms of the affordance *feature-ability* relation, are presented. The recommendations emanating from the study as well as possible research gap avenues are also suggested.

6.1 Introduction

The conclusions regarding the causal mechanisms involved in affordances as well as the proposed affordance formalism are presented in this section. The affordances have been described as generative mechanisms with a conditional event or *concrete outcome* causing potentialities capable of generating (Bygstad et al., 2016; Volkoff & Strong, 2013).

As relational constructs affordances have been theorised as a relation between the features of artefacts and the abilities of the social actors to use the artefact features (see formula [Aff1]). The underlying constitutive structural elements of both feature and ability relational constructs of affordances were also explored.

Through a critical realist retroductive process, the nature and aspects of affordance were explored and formalised. Based on the findings from the exploration, the recommendations and suggestions for further research will be advanced.

6.2 Ability

Ability is to be able to do something or to appropriately and/or effectively execute actions based on set rules (Zahle, 2017). Ability is practical knowledge or experiential know-how (Alter, 2001; Cath, 2009).

6.2.1 *Ability structural elements*

Based on the *narrative* synthesis (Schryen et al., 2020), of the extant literature, it was proposed that the plausible underlying structural elements the '***ability'*** construct are: *know-how* $\boldsymbol{KH_S}$ knowledge to accomplish an *achievement* $\boldsymbol{A_S}$ by *procedural dexterity* $\boldsymbol{P_S}$ of using an artefact, motivated by *goal* $\boldsymbol{W_S}$ under specified *state of*

affairs $\boldsymbol{K_S}$ (Alter, 2001; Cath, 2009; Ossorio, 2010, pp. 33–43, 53). The ability construct of affordances was posited as the five-parameter construct: ($\boldsymbol{W_S}$, $\boldsymbol{K_S}$, $\boldsymbol{KH_S}$, $\boldsymbol{P_S}$, $\boldsymbol{A_S}$), proposed by Ossorio (2010) and formalised as follows (see formula [Bh2]):

Ability = ($\boldsymbol{W_S}$, $\boldsymbol{K_S}$, $\boldsymbol{KH_S}$, $\boldsymbol{P_S}$, $\boldsymbol{A_S}$), [Bh2]

where *know-how* $\boldsymbol{KH_S}$ knowledge, *achievement* $\boldsymbol{A_S}$ by, performance or *procedural dexterity* $\boldsymbol{P_S}$, motivation $\boldsymbol{W_S}$, and *state of affairs* $\boldsymbol{K_S}$ are its *structural elements* (Ossorio, 2010, pp. 33–43, 53).

6.2.2 *Ability causal mechanisms*

In terms of the critical realist structural re-descriptions, the five-parameter ability construct:($\boldsymbol{W_S}$, $\boldsymbol{K_S}$, $\boldsymbol{KH_S}$, $\boldsymbol{P_S}$, $\boldsymbol{A_S}$) was re-described as (a) know-how $\boldsymbol{KH_S}$ knowledge was re-described as the *structure*; (b) the procedural dexterity $\boldsymbol{P_S}$ re-described as *mechanism*; (c) motivation $\boldsymbol{W_S}$ re-described as *mechanism reasoning*; (d) achievement $\boldsymbol{A_S}$ re-described as a social event or outcome of mechanism; (e) *state of affairs* $\boldsymbol{K_S}$ re-described as specified *conditions* (Dalkin et al., 2015; Easton, 2010; Ossorio, 2010, pp. 33–43, 53; Tsang, 2014). As a structural causal conjuncture or causal mechanism, 'ability' can cause observed *social event* $\boldsymbol{A_S}$, as follows:

> $\boldsymbol{Ce_1}$**:** the *empirical social event* $\boldsymbol{A_S}$ is the observed actual *social event* $\boldsymbol{A_S}$, that is caused by social *mechanism* ($\boldsymbol{P_S}$,$\boldsymbol{W_S}$) of the $\boldsymbol{KH_S}$ social *structure* under specified $\boldsymbol{K_S}$ social *conditions* (i.e. pure social conjunctures without material technology artefact contribution).

6.3 Features

Technology features, in general, are component building blocks of technology (Griffith, 1999) or structural/functional properties of technology (Cheikh-Ammar, 2018). Technology features are also its *functional* properties (Asnina, 2013; Osis et al., 2008, 2007; Osis & Asnina, 2011; Osis & Donins, 2017) or actionable characteristics (rules) and resources for action (DeSanctis & Poole, 1994).

6.3.1 *Feature structural elements*

The extant literature describes the underlying structural elements of the '*feature*' construct as technology component entity $\boldsymbol{Ex_F}$ that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving or using action linked *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$, and formalised as follows (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

feature = ($\boldsymbol{A_F}$, $\boldsymbol{R_F}$, $\boldsymbol{O_F}$, $\boldsymbol{Pr_F}$, $\boldsymbol{Ex_F}$), [Ff2]

where *entity* $\boldsymbol{Ex_F}$ is technology component that can achieve *results* $\boldsymbol{R_F}$, by executing an *action* $\boldsymbol{A_F}$, involving or using action linked *object* $\boldsymbol{O_F}$, under *preconditions* $\boldsymbol{Pr_F}$, are its *structural elements* (Asnina, 2013; Osis et al., 2008, 2007; Solomencevs, 2016).

6.3.2 *Feature causal mechanisms*

In terms of the critical realist structural re-descriptions, the five-parameter *feature* constructs: (a) component technology *entity* $\boldsymbol{Ex_F}$ was re-described as the *structure*; (b) *action* $\boldsymbol{A_F}$ re-described as *mechanism*; (c) *results* $\boldsymbol{R_F}$ re-described as event or outcome of mechanism; (d) *preconditions* $\boldsymbol{Pr_F}$ re-described as specified *conditions*; and (e) the *object* $\boldsymbol{O_F}$ involved or used in *action* $\boldsymbol{A_F}$ (a mechanism), was re-described as *mechanism resource* (Asnina, 2013; Dalkin et al., 2015; Easton, 2010; Osis et al., 2008, 2007; Solomencevs, 2016; Tsang, 2014). As a structural causal conjuncture or causal mechanism, 'ability' can cause observed empirical events as follows:

$\boldsymbol{Ce_2}$: the *empirical material event* $\boldsymbol{R_F}$, is the observed actual *material event* $\boldsymbol{R_F}$, that is caused by *material mechanism* ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$) of the $\boldsymbol{Ex_F}$ *material structure*, under specified $\boldsymbol{Pr_F}$ *material conditions*. These are pure *material* conjunctures without social agency contributions.

6.4 Affordances

In terms of actor-artefact relations, affordances are relational action potentials for achieving concrete outcomes between goal-directed actors and artefacts (Volkoff & Strong, 2013). As relational constructs, affordances are emergent or caused by the interaction of; (a) '*ability' conditional-causal-structure* (***KH$_S$***,***K$_S$***) (i.e. *know-how* ***KH$_S$*** knowledge, under the specified *state of affairs* ***K$_S$***), as well as the social mechanism (***P$_S$,W$_S$***) or motivated *procedural dexterity* ***P$_S$***, with intention ***W$_S$***; (b) interacting with '*feature' conditional-causal-structure*: (***Ex$_F$***, ***Pr$_F$***) (i.e. component technology entity ***Ex$_F$*** under specified *preconditions* ***Pr$_F$***), as well as the mechanism (***A$_F$***,***O$_F$***) or entity action ***A$_F$*** involving action linked *object* ***O$_F$***. The combined *actor-artefact* structural interaction causes the emergence of the sociomaterial *mechanism*: (***A$_F$***,***O$_F$,P$_S$,W$_S$***). Thus, it is proposed that the agent affordance formalism (see formula [Aff1]) (Chemero, 2003; Şahin et al., 2007), can be expressed as an afforded action conditionality formula [Aff1.1] below:

affordance = *affords*-**ϕ** (*features*, *ability*) [Aff1]

> ***where affords*-ϕ** refers to the combined *actor-artefact mechanism* or sociomaterial mechanism (***A$_F$***,***O$_F$,P$_S$,W$_S$***);
>
> ***where feature*** refers to the *conditional-causal-structure* of component technology *entity* ***Ex$_F$*** (*structure*), with its contingent conditionality ***Pr$_F$***, i.e. (***Ex$_F$***, ***Pr$_F$***);
>
> ***where ability*** refers to the *conditional-causal-structure* of social actor know how ***KH$_S$*** (*structure*), with its contingent conditionality ***K$_S$***, i.e. (***KH$_S$***,***K$_S$***);
>
> ***and thence***;

affordance = (***A$_F$***,***O$_F$,P$_S$,W$_S$***) ((***Ex$_F$***, ***Pr$_F$***), (***KH$_S$***,***K$_S$***)) [Aff1.1]

In the context of digital technologies, affordances (digital technology affordances) are emergent or caused by *feature-ability* interactions involving any of the possible digital communicative interactions — *chronemics*, *proxemics*, *kinesics*, o*culesics*, v*ocalics*, *textual*, and *verbal* communicative interactions (Feine et al., 2019; Saunderson & Nejat, 2019; Singh, 2011). Thus, the structural interactions, causes the emergence of

the combined *actor-artefact* sociomaterial *mechanism*: (***A$_F$***,***O$_{F,}$P$_{S,}$W$_S$***), that can cause the following afforded *social event* ***A$_S$***, *material event* ***R$_F$***, and/or *sociomaterial event* (***R$_F$***,***A$_S$***) under appropriate *contingent* digital technology *conditions* as follows:

Ce$_1$*:** the *empirical social event* ***A$_S$ is the observed actual *social event* ***A$_S$***, that is caused by social *mechanism* (***P$_{S,}$W$_S$***) of the ***KH$_S$*** social *structure* under specified ***K$_S$*** social *conditions*. These are pure social conjunctures without material technology contributions.

Ce$_2$*:** the *empirical material event* ***R$_F$, is the observed actual *material event* ***R$_F$***, that is caused by *material mechanism* (***A$_F$***,***O$_F$***) of the ***Ex$_F$*** *material structure*, under specified ***Pr$_F$*** *material conditions*. These are pure *material* conjunctures without social agency contributions.

Ce$_3$*:** the *empirical social event* ***A$_S$ is the observed actual *social event* ***A$_S$***, that is caused by the *sociomaterial* structural *mechanism* (***A$_F$***,***O$_{F,}$P$_{S,}$W$_S$***) emerging from the *material structure* ***Ex$_F$*** *and* the social *structure* ***KH$_S$*** under specified ***K$_S$*** social *conditions*.

Ce$_4$*:** the *empirical material event* ***R$_F$ is the observed actual *material event* ***R$_F$***, caused by the *sociomaterial* structural *mechanism* (***A$_F$***,***O$_{F,}$P$_{S,}$W$_S$***) emerging from the *material structure* ***Ex$_F$*** *and* the social *structure* ***KH$_S$*** under specified ***Pr$_F$*** *material conditions*.

Ce$_5$*:** the *empirical sociomaterial event* (R$_F$***,***A$_S$***), is the observed actual *sociomaterial event* (***R$_F$***,***A$_S$***) caused by the *sociomaterial* structural *mechanism* (***A$_F$***,***O$_{F,}$P$_{S,}$W$_S$***) emerging from the *material structure* ***Ex$_F$*** *and* the social *structure* ***KH$_S$*** under specified *sociomaterial conditions* (***Pr$_F$***,***K$_S$***).

Ce$_6$*:** the *empirical sociomaterial event* (R$_F$***,***A$_S$***), is the observed actual *sociomaterial event* (***R$_F$***,***A$_S$***), caused by incidental *sociomaterial* concurrence of causal explanation ***Ce$_1$*** and ***Ce$_2$***.

Ce$_7$*:** the *empirical social event* ***A$_S$, is the *empirical* misinterpretation of causal explanation ***Ce$_5$*** and/or ***Ce$_6$*** in favour of social causality.

Ce$_8$*:** the *empirical material event* ***R$_F$, is the *empirical* misinterpretation of causal explanation ***Ce$_5$*** and/or ***Ce$_6$*** in favour of material causality.

6.5 Recommendations

The study has explored the implied actor-artefact relation in the form of *features* and *abilities* in the context of affordances. The underlying structural elements of both feature and ability was explored to explore their causal mechanisms. The purpose of the structural exploration was to establish the affording mechanisms of affordances.

Eight plausible causal arrangements or causal explanations were retroduced from the underlying structural elements — $\boldsymbol{Ce_1}$, $\boldsymbol{Ce_2}$, $\boldsymbol{Ce_3}$, $\boldsymbol{Ce_4}$, $\boldsymbol{Ce_5}$, $\boldsymbol{Ce_6}$, $\boldsymbol{Ce_7}$, and $\boldsymbol{Ce_8}$. Out of the eight two ($\boldsymbol{Ce_1}$, and $\boldsymbol{Ce_2}$) were found to be atypical of affordance causal logic, in the traditional IT sense of the *elementary interaction loop*. However, in the context of digital technologies where the actor-artefact interaction transcends *space*, *time*, *actor*, and *artefact* experiential dimensions, these atypical causal mechanisms were found to be plausible at least. This is because with digital technologies the automaticity and artificial agency is possible, using technologies such as artificial intelligence, and augmented reality, robotics, etc.

The eight causal explanations were corroborated by comparison with the extant literature on actor-artefact causal relations (see Table 6) (Markus & Robey, 1988; Markus & Rowe, 2018). The exercise generated what could be considered a useful typology of affordance causal mechanisms. It thus recommended that the eight causal mechanisms may be used as a typology of affordance causal mechanisms contributing to the conceptualisation of affordances (see Table 6).

Furthermore, based on the structural retroductive process, it was discovered that the actual affording logic was the *actor-artefact structural mechanisms* as well as the *structural conditions* of each entity. The implied affordance actor-artefact relation of *feature* and *ability* was thus revised as follows:

$$affordance = affords\text{-}\boldsymbol{\phi}\ (features, ability) \qquad [Aff1]$$

$$affordance = (\boldsymbol{A_F},\boldsymbol{O_F},\boldsymbol{P_S},\boldsymbol{W_S})\ ((\boldsymbol{Ex_F}, \boldsymbol{Pr_F}), (\boldsymbol{KH_S},\boldsymbol{K_S})) \qquad [Aff1.1]$$

Where ($\boldsymbol{A_F}$,$\boldsymbol{O_F}$,$\boldsymbol{P_S}$,$\boldsymbol{W_S}$) refers to the *actor-artefact mechanism* and (($\boldsymbol{Ex_F}$, $\boldsymbol{Pr_F}$), ($\boldsymbol{KH_S}$,$\boldsymbol{K_S}$)) refers to the conditional affording structural properties of the actor-artefact relation.

6.6 Suggestions for further research

Eight causal explanations that were retroduced through a critical realist reductive process — ***Ce$_1$***, ***Ce$_2$***, ***Ce$_3$***, ***Ce$_4$***, ***Ce$_5$***, ***Ce$_6$***, ***Ce$_7$***, and ***Ce$_8$***, are provisionally presumed relevant valid, in the context of the current study. However, possible synthesis research involving a multitude of triangulated methods could be conducted to empirically verify each causal case, as well as confirm or disprove their plausibility. Such synthesis research would need to integrate several, *concrete*, *abstract* and, *generalisation* methods to explore the nature of the affordance causal constructions and the nature of action potentiality.

Furthermore, the typology of affordance causal explanations (see Table 6) mapped to the theoretical relevant theories could useful input to ongoing research on affordance causality in general. But also, it could be improved or disproved through further empirical studies.

The affordance *features* and *abilities* actor-artefact relation could also be explored further in the context of the *sociomaterial routines.* According to Gaskin et al., (2014) *sociomaterial routines* can be formalised as a parametric construct: (***A****,* ***Actor****,* ***L****,* ***M****,* ***Aff****,* ***Art****,* ***Df***), where activity type ***A****,* actor configuration ***Actor****, activity location* ***L****; tool modality* ***M****, tool affordance* ***Aff****, artefact type* ***Art****, and dataflow* ***Df****,* are its generative elements (Gaskin et al., 2014). Thus, the *tool affordance* ***Aff****,* are considered to be constitutive of *sociomaterial routines*, which may need further exploration.

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