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# Towards a Unified Conceptualisation of IS Agility

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***Abstract*—Information system (IS) agility has been consistently ranked high by executives in various surveys conducted in the past decade. However, the concept of agility lacks clarity and specification, which can hinder our efforts accumulating knowledge and comparing studies. Based on a comprehensive conceptualisation, we compare agility with commonly confused concepts such as flexibility, evaluate four key capabilities of agility, and identify four categories of agility relevant to IS research.**

***Keywords—Agility, Information Systems Agility***

## I. Introduction

Being agile in a dynamic business environment has been rated by executives at the top of their wish list. In a global survey, 89% of over 1.500 respondents indicated that agility is "very" or "extremely" important, while 91% perceived the increasing importance of agility [1]. Another survey ranked agility third among the top ten IT management concerns [2]. More recently, agility has been advocated as a critical topic to both IS research and practice [3]. IS agility has also been highlighted as a key pillar of modern businesses [4-6]. A survey of 660 CIOs found out that the inability of IT systems to respond quickly to business changes is a genuine concern [7].

Despite the significance of the topic, two concerning issues have emerged from our literature review. One is the lack of distinctiveness. Mixing agility with other concepts, specifically flexibility, is not uncommon. Many articles even use these terms interchangeably [8, 9]. Such terminological fuzziness leads to difficulties in conceptualisation and operationalization of constructs. The second issue is that very limited efforts have been made to illuminate how IS agility can be achieved by design. Most studies have taken a "hindsight" approach by evaluating proclaimed agile organizations, projects, systems, and processes, and paid abundant attention on organisational aspects, such as strategic planning, business culture and climate. Yet little guidance can be found for designers to purposely craft IS artefacts that deliver agility.

Both issues need to be addressed effectively. In fact, to propose valid design guidelines for IS agility, one must address the first issue with rigour. The lack of consistency and distinctiveness not just bewilders designers and researchers, but can hinder the IS research community from building up cumulative knowledge [10]. Due to the page limits, we focus only on the first issue in this paper. This paper proposes a systematic approach to characterise the concept of agility in the IS context. We bring up "conceptual clarity" by comparing agility with flexibility. Next, we elaborate on the "structural integrity" of agility. Finally, we suggest an Agility Pyramid to integrate the current research on IS agility.

## II. What is Agility?

### A. Agility vs flexibility: Establishing conceptual clarity

IS appears to be a fertile field for popular but weakly defined concepts [11]. IS agility is such a case. Its vagueness has caused problems in differentiating the concept from others and in establishing it as a legitimate IS construct. The development of a valid conceptualisation of IS agility has been difficult and is still in an early stage [12]. The difficulties largely come from its multi-faceted nature [13]. IS agility is a particular instance of the general concept of agility [14]. Therefore establishing a good conceptualisation in general is essential to define IS agility. To understand the general concept, we reviewed the related literature. Given the plasticity of the abstract concept (used e.g. in sports, business, and software development) and the multidisciplinary nature of approaches (e.g. business strategy, emergency management and resilience engineering), the literature review extends from sports science to business and IT management. The purpose of this review is to elaborate on the essential meaning of agility and to establish a proper theoretical foundation for future research.

Confusing agility with flexibility seems to be a common mistake. Exploring the origins of agility and flexibility helps to clarify and differentiate these two concepts. However, business researchers admit the two concepts are "diverse concepts that are hard to grasp" [15]. Part of the reason is that both were imported from other disciplines. Both terms have been originally used in sports science as key predictors to athletic performance. Therefore it is reasonable to look to the sports science literature as a mature source of knowledge.

In sports science, agility has been related to temporal and spatial uncertainties. Agility is critical to athletes' performance in many competitive sports. This capability is defined as *a rapid whole body movement with change of velocity or direction accurately in response to a stimulus* [16]. It involves reaction time and velocity. Reaction time is the *minimum time from the presentation of a stimulus to the onset of a response*, and velocity is *the rate of change in position with respect to time* [16]. Consequently, agility in sports is a concept incorporating the ideas of speed, coordination, reflex, and balance, all under one common umbrella.

According to sports science literature, agility has two major components: decision and change [16]. The decision part concerns perceptual activities including stimuli recognition, visual scanning, pattern recognition, understanding unfolding events, and anticipating future status. All these should be done before the subsequent change of direction or speed can take place. The change part refers to the physical execution of a decided response. The quality of the execution is determined by multiple factors such as technique, strength, balance, and so forth [16]. Agility tests often involve multiple changes in direction and velocity, and the result is judged by the time taken to finish the test.

Flexibility is also a frequently mentioned concept in sports science literature. Though related to change, flexibility does not involve uncertainty and speed. It is often defined as the total "achievable excursion" of a body part through its potential range of motion in a smooth, easy, unrestricted, and pain free manner [17]. This emphasis on range means that flexibility can be evaluated with tests such as a "sit and reach" in which the testee is asked to reach both arms forward while sitting on the floor with straight legs. Depending on the particular sport, flexibility is often not as critical as agility. For instance, cricket players do not need to be as flexible as gymnasts, but they do need a higher level of agility to be able to hit and run to win the game.

In many sports, agility training is used as a key means to improve performance, whereas flexibility training is considered supportive for preventing injuries [17]. Table 1 summarizes the main differences between agility and flexibility.

Table 1: Agility versus flexibility in sports science

| | **Agility** | **Flexibility** |
|---|---|---|
| Emphasis on speed | Yes | No |
| Emphasis on range | No | Yes |
| Uncertainty | Yes | No |
| Measurement | Response time | Capability range |
| Purpose | Improving response | Widening response |

A good definition should include a genus and differentia, the former describing a category of the thing to be defined, and the latter distinguishing the thing from others in the same category [14]. The definitions of agility and flexibility provided by sports science literature meet these criteria. They both concern motion, but one concerns completion time while the other concerns range. However, most definitions used in the IS literatures do not. Hence in this study, the differentia shown in Table 1 is used to review the agility and flexibility concepts used by the IS discipline. For instance, if a reference to flexibility includes notions of uncertainty and speed, it is treated as agility. On the other hand, if a study has a reference to agility but does not use these notions, it is excluded.

## *B. Definitions of agility in IS research*

Guided by the differentia established in sports science, we can now identify rigorous agility conceptualisations in the IS literature (Table 2). These definitions elucidate that "sense" and "respond" are the core components of agility [18].

*Table 2: Definitions of agility in IS literature*

| **Definitions** | |
|---|---|
| Ability to **detect** and **seize** market opportunities with speed and surprise | [19] |
| **A response** to the challenges posed by a business environment dominated by **change and uncertainty** | [20] |
| Ability of firms to **sense environmental change** and **respond** readily | [18] |
| Ability to **sense and respond to changes** in an organisation's **internal and external environment** by quickly assembling resources, relationships and capabilities | [21] |

## *C. Sense and respond models: A behavioural view of agility*

"Sense" and "respond" are not brand new notions and have long been studied in other fields. For instance, military researchers have been developing models and theories to improve responsiveness based on sense and respond behaviour. Table 3 provides a list of other models we found.

*Table 3: "Sense and respond" models*

| **Model** | **Behavioural components** | |
|---|---|---|
| SDSE | Sense-Diagnose-Select-Execute | [14] |
| SARI | Sense-Interpret-Analyse-Decide-Respond | [22] |
| SIDA | Sense-Interpret-Decide-Act | [23] |
| SPCDA | Sense-Process-Compare-Decide-Act | [24] |
| SHOR | Stimulus-Hypothesis-Option-Response | [25] |
| OODA | Observe-Orient-Decide-Act | [26] |

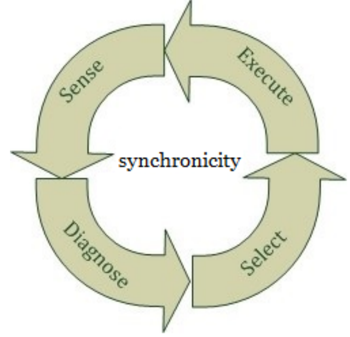
The OODA model developed by Boyd for the US Air Force is considered a seminal work. OODA is a training instrument for fighter pilots. Pilots who learn to "cycle through" the behavioural components faster than their opponents will prevail in dogfights where agility overtakes raw power.

In business studies, SIDA was proposed to explain the transformation of modern businesses from "Make and Sell" to "Sense and Respond" in an information age [23]. The importance of the "sense and respond" lens in IS was argued by Sambamurthy in a influential MISQ paper [19] and used in subsequent studies [18]. Since these pioneering works in IS, other similar models have been published, e.g. SARI [22] and SDSE [14].

## *D. Agility and synchronicity*

All "sense and respond" models affirm a cyclic view of how agility can be achieved. Based on these models and following recent terminology [14], we propose the "agility cycle" (Figure *1*) as a means to illustrate that agility is not a one-off effort, rather, it is continuous readiness for change. We also introduce the concept of "synchronicity" to highlight the time dimension of agility.

Figure 1: Agility cycle in business



**Sensing.** Is about detecting and collecting signals from the business environment that suggest need for change. This is arguably essential to initiate response, as the sensing capability of an organisation determines what changes can be observed [18, 19]. If the sensing capability is flawed, the organisation may delay change, or worse, may initiate an incorrect response. Given organisations have limited resources, the consequences of flawed sensing may range from cost increases to loss of market share and competitive advantages [14].

**Diagnosing.** Is about filtering and interpreting signals. Filtering involves separating valid signals from noise [14]. It is imperative for organisations operating in a "globally wired", information intensive marketplace [27] usually overloaded with information. Without filters, organisations can be overwhelmed or even paralysed by information. Interpreting is also a critical phase of diagnosing. Once a stimulus for change is sensed, it needs to be analysed and understood before any response can be made. Accurate diagnosis allows the organisation to ascertain the nature and cause of the change [14]. An important objective of diagnosis is to detect patterns and trends by collectively interpreting signals that individually may be too small to indicate a change [14].

**Selecting.** Once a change is diagnosed, a response should be selected. This is the process of choosing an hypothesis about a situation and response to it [28]. A response can be as big as "change the process" or as little as "keep an eye on it". Criteria for selecting a response need to be set. The six metrics—time, cost, scope, ease, quality, and robustness—defined by Dove may be used as a reference to assess possible responses [29]. Ideally an agile business should be capable of continuously selecting responses within the time constrains and without compromising cost, quality, scope, and robustness [30]. In reality, a "quick patch job" that can be done in time may be more valuable than a robust solution done too late [30].

**Executing.** Is the process of testing the chosen hypothesis by acting on the selected response [28]. This stage is where flexibility also plays a role. An inflexible entity may find executing a given response harder than a flexible one does. However, if an inflexible organisation senses a change way before the flexible one even noticed, it might start responding much earlier than the flexible one. Therefore, being flexible is not a sufficient condition to agility. Even though flexibility can help, a flexible organisation may not be agile if it is unable to detect and decide quickly.

Execution involves disseminating decisions and supervising changes through feedback [27]. This stage is a critical part of the agility cycle [14], as a successful execution requires excellence in coordination between multiple aspects of the selected response (e.g. time, cost, scope, etc.) As the last stage of the agility cycle, execution's failure can effectively negate the results of the previous stages.

In a large organisation, multiple agility cycles may be processed concurrently. Reconciling these multiple cycles requires more effort in coordination and communication than does focusing on a single one. Therefore an additional layer of orchestration or federation needs to be considered when designing an agile system.

**Synchronicity.** The time dimension, often interpreted as "speed", is a critical factor in the agility concept. Being agile presupposes being time-sensitive. This is a key property that differentiates agility from other concepts such as flexibility. In this paper, this time dimension is described as "synchronicity", which emphasizes a timely flow from one phase to the next without undesirable bottlenecks. Synchronicity is a popular concept in Computer-Supported Collaborative Work (CSCW). It defines that the Respond phase should occur within a certain acceptable period of time next to the Sense phase (hereafter denoted by ΔS-R). In business, this ΔS-R varies drastically across industries. For instance, in textile manufacturing, days or weeks are acceptable values of ΔS-R, whereas in stock trading these can go down to seconds.

Defining ΔS-R is essential for agile entities. Previously such time constrains have often been vaguely described as "quickly" [21, 31], "rapidly" [31, 32], "with speed" [19], "real time" [14], or "right-time and on-demand" [33]. All these terms are vague attempts to capture the sense of urgency that inheres in agility. However, the terms "quickly, rapidly, with speed" may be too ambiguous, whereas "real time" may be too radical and may only happen in an ideal world (though Pankaj suggested that "real time" does not necessarily means instantaneous, this term may still sound utopian and cause terminological confusion).

The notions of synchronicity and ΔS-R provide more conceptual clarity than the predecessors by depicting a specific and realistic time frame within which agile businesses should perform. Since business is about competition, it is not the absolute speed that matters, but rather the speed relative to one's customers and competitors [27]. As long as an organisation can maintain a higher tempo of actions relative to customers and competitors, it is agile enough to cope with the challenges and reap the opportunities.

### *E. Other notions not to be confused with the agility cycle*

Besides agility, other concepts have been developed to explain business behaviour in turbulent environments, such as absorptive capacity [34], strategic flexibility [35], dynamic capabilities [36], and improvisational capabilities [37]. However, these concepts largely zero in on strategic issues, whereas the concept of agility can apply to not only strategic issues, but also to tactical and operational issues. Strategic issues are distinct from tactical or operational issues [38]. Therefore IS researchers have urged to treat agility as a unique notion distinct from the aforementioned concepts [18, 37].

## III. Agility by design: The IS Agility Pyramid

As a hot topic in IS research, agility studies have seen a diverse range of interests stretching from organisational culture and climate, to system design and development. In this paper, we focus exclusively on a design perspective. On the surface, IS agility has two sides: Agility in the system development process; and agility in the system's operation [39]. The former, hereafter termed "Dev Agility", involves the interplay between the system and its developers to make functional changes, whereas the latter, hereafter termed "Ops agility", is mainly concerned with the interplay between the system and its users. "Dev agility" can be seen as a capability of a system and of a development team. It involves developers working on systems that are meant to be continuously modified, in situations where clients cannot provide clear requirements, which in turn change frequently even when the coding phase has started [40]. Ops agility is more a capability of a system and of its users. It is related to how well a system is designed to support users changing their behaviours [41]. Such a dichotomous classification is in alignment with the recently popular notion "DevOps" [42].

Our literature review enabled us to identify a finer, four-category classification of IS agility. The three categories at the bottom of the Agility Pyramid shown in Figure 2 target different aspects of "Dev Agility". The category at the top of the pyramid is concerned with "Ops Agility".

*A. Dev Agility*

**Responsive Development Methodology.** This category concerns approaches to system development processes that allow development teams to maintain a high-level of responsiveness when faced with new requirements. This research area is the most active among all four categories in the Agility Pyramid and is mainly focused on Agile Methods like Scrum and XP. These methods suggest principles and practices emphasizing people over processes, short iterations, and close collaboration between development teams and clients [43].

Agile methods are believed to revolutionize software development and have been passionately adopted by many organisations. IS researchers have been studying the impact of these methods, e.g. in project success [44], management [45], leadership [46], and so on.

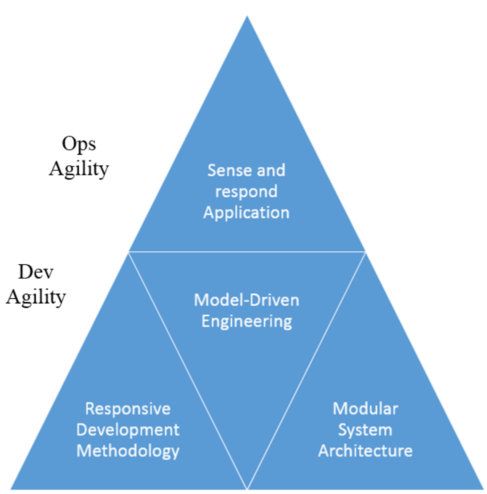



*Figure 2. IS Agility Pyramid*

**Modular System Architecture.** This category concerns the means to implement architectural flexibility in IS. System architectures can be constructed to support easy and quick changes. This research area focuses extensively on design patterns and architectural principles such as modularity and reusability. Many studies can be found on long-standing topics such as objected orientation, service-oriented architectures [47], aspect-oriented programming, etc. These techniques are mainly concerned with designing loosely coupled system components whose behaviour can be modified in isolation.

**Model-Driven Engineering.** The main purpose of this category is to look for design approaches that support agile specifications. Topics in this category are relatively diverse and come from different areas in computer science and IS. This includes for instance Business Process Management, which promote the separation of two important concerns: activity execution and process modelling. In particular, Process Aware Information Systems are capable to automatically adapt the execution to model changes, which can be easily done using visual modelling tools. These changes can be done fast, especially when compared with the more traditional software line-by-line coding. Similar design approaches can be found in database development, model driven development, and user-interface development. So, one overarching aspect of this category is making systems more agile through modelling.

In these systems, models often take a prescriptive role. That is, there is an engine that determines what information processing activities are required/allowed according to the prescribed model. This prescriptive role represents a significant constraint to our concept of agility, as users are constrained to what has been defined at design time. In our view, both agility and flexibility emerge from being able to overcome model prescriptions is response to environmental changes. For instance, whenever an unexpected event occurs and the model does not have a correct procedure. Note that the problem is not that computers always have rigid control over users. That is not the case. For instance, a document editor or a chat tool are good examples where computer control is low. The problem is that models are often used in prescriptive ways. Research developments such as coordination models [48] and dynamic workflow management [49] attempt to overcome this problem and in their own way contribute to increase agility.

*B. Ops Agility*

The aforementioned three categories are the main pillars of "Dev Agility". However, with Dev Agility only, a business may find itself seeing new IS releases—with new features being implemented and old bugs being fixed—quickly and frequently, but with no guarantee that such releases will respond to major environmental changes. "Ops Agility" is concerned with new threats and opportunities, evaluating options, deciding on courses of action to counter the threats or reap the opportunities, executing the actions, monitoring the progress of the chosen actions, collecting feedback, and more importantly, the ability to get all these steps done synchronically in the market-defined timeframe (ΔS-R).

**Sense and respond application**. This category concerns the combination of system design and user interactions in applications that can help businesses to sense and respond to environmental changes in an on-demand manner [50]. Two key technological frameworks being investigated in this category are Complex Event Processing and Information Fusion. Research in this category often focus on practical applications in specific areas such as banking fraud detection [51] and algorithmic stock trading. Studies in this category hypothesise that any system should have "sense and respond" functionalities. With comprehensive event and rule definitions, many responses can be automated. Users are allowed to define rules, add sensors and alerts, and create responses.

*Table 4: Key research topics in IS agility*

| | Categories | Key Topics |
|---|---|---|
| **Dev Agility** | Responsive Development Methodology | Agile Methods (Scrum, XP, etc.) [52] |
| | Model-Driven Engineering | Coordination Mechanisms [48], Dynamic Workflow [49] |
| | Modular System Architecture | Service Oriented Architectures [47], Object Orientation, Aspect Orientation |
| **Ops Agility** | Sense and Respond Application | Complex Event Processing [22], Information Fusion |

In a nutshell, the Agility Pyramid articulates IS agility as a set of independent research topics. Table 4 summarises key topics covered in each category. To achieve true IS agility, the articulation of all four categories is needed.

## IV. CONCLUSION

By articulating different aspects of agility, this paper provides valuable conceptual clarity to both the research community and industry. Future research should acknowledge the distinctiveness of the concept and use the term with greater discipline. This paper reviews definitions, models and practices relevant to the agility concept. We propose a cyclic view of agility, which has its root in non-IS fields (i.e. military, sports, business). Similar to rugby teams in a competitive game or jet fighters in a dogfight, agile IS are necessarily complex, non-linear, unpredictable and continuously changing [27]. Organisations capable to execute the Agility Cycle faster than their competitors are more agile and may prevail over less capable ones [27].

We introduce the concepts of synchronicity and ΔS-R to solidify the structural integrity of agility. The integration of the time dimension is an important step towards an actionable and measurable plan for achieving agility. Future research could attempt to capture the values of ΔS-R across various industries, i.e. what are the undesirable, acceptable, and optimal values of ΔS-R in the banking industry compared to logistics? How to effectively incorporate these values in IS design?

This paper, moreover, proposes an Agility Pyramid integrating agility concepts from different domains. We suggest four categories including Sense and Respond Application, Responsive Development Methodology, Model-Driven Engineering, and Modular System Architecture. Currently, when "IS agility" is cited, the corresponding dimension is often unclear or ambiguous, which in turn can cause mismatched expectations and conflicts. The four categories we identify provide both researchers and practitioners with a well-grounded specification of IS agility.

Last but not least, as a part of a larger research project, this paper lays the theoretical foundations for more agile IS systems. Based on the Agility Pyramid, we can deductively create tools for IS designers and researchers to identify bottlenecks that decrease IS agility, as well as key factors that increase IS agility. Such tools may help eliciting and justifying system requirements, design decisions, and software development methods.

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