



# Assessing the value of decentralized and interoperable data storage for service providers

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## Abstract

This article identifies how decentralized and interoperable storage solutions create value for service providers. These solutions are invented to serve the fundamental principle that data should not be confined behind company walls. Instead, these solutions facilitate the flow of data between different stakeholders, enabling innovation in data ecosystems through the reuse of information. Through multiple stakeholder interviews, this research explored different ways in which such solutions bring value to service providers. Utilizing the affordance theory, we conclude that, compared to relating technologies such as blockchain and big data analytics, decentralized and interoperable storage solutions bring two additional opportunities; (1) an affordance on interoperable data exchange which enables the reduction of costs (e.g., data cleaning) and (2) an affordance on legal risks and compliance facilitating the reduction of compliancy costs and potential legal risks.

**Keywords** Affordances · Decentralized and interoperable storage · Solid · Capabilities · Data ecosystems

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## 1 Introduction

Service providers deliver services (e.g. SaaS offerings) and often gather an extensive amount of data to enhance their service quality and extend their offering (Rountree 2013; IDS Association 2021). These data are often secluded behind company walls in so-called silos. Given this protective attitude of service providers towards data, they are often reluctant to share it with other stakeholders (Van Kleek and OHara 2014). This cautious approach comes with several drawbacks, including the significant time and financial investments required for data lifecycle management, coupled with the challenges of obtaining qualitative data (Machado et al. 2022). Consequently, this reluctance to exchange data and insights slows innovation down (Van Damme et al. 2022).

The decentralization of data storage in combination with the interoperability of data and systems is proposed as a solution for this issue, leading to the decoupling of information and applications (Machado et al. 2022; Werbrouck et al. 2019). As a result, accessibility to the data is facilitated for multiple parties. Coupled with linked data, particularly utilizing RDF (Resource Description Framework), this approach streamlines collaboration among different organizations. The linking of the data and semantically enrichment of the data allows digital agents to interpret and utilize the data more efficiently. Consequently, the enhanced interoperability facilitates broader ecosystem-wide data sharing and collaboration and consequently provides opportunities for innovation.

Given that decentralized and interoperable storage solutions (DIS) are only recently gaining momentum, limited research is available concerning the added value for service providers. This article will focus on one specific technology, Solid, to obtain decentralized and interoperable storage. The Solid specification was created by Tim Berners-Lee, the inventor of the World Wide Web. The purpose of Solid<sup>1</sup> (Capadisli et al. 2021; Werbrouck et al. 2019) is to create interoperable ecosystems of applications and data while simultaneously empowering individuals to participate in the data-sharing process. Data can be stored in Solid Pods, allowing multiple parties to access the data in those pods. However, data are only accessible after access is granted by the one controlling the pod (e.g. an end-user, data subject or a company). A person or company can host a pod themselves or use one hosted by a third party. This way, a data ecosystem of Solid pods is created (Buyle et al. 2020).

For the opportunities of Solid to materialize, service providers should understand the capabilities this technology offers. Additionally, these capabilities need to solve the identified challenges these service providers put forward. Currently, there is a lack of research on the capabilities for service providers and the related benefits of Solid-based (or comparable technological) implementations. Previous research mentioned that a first research objective should be understanding the relationship between technical requirements and the value-creating potential in a digital ecosystem based on personal data vaults (Verbrugge et al. 2021). This article aims to provide a first contribution.

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<sup>1</sup><https://solidproject.org/>.

Research has shown that affordance theory offers a promising avenue for gaining valuable insights into the potential of information systems for companies (Carlo et al. 2012; Leonardi 2011). This article applies affordance theory in the context of DIS (e.g. Solid) for service providers. Affordances refer to the perceived or actual capabilities of a technology that users can leverage for specific purposes (Gibson 2014). This article aims to identify the capabilities and advantages these technologies bring for service providers. Through analysis of the capabilities, this article translates technical specifications, such as the Solid protocol (Capadisli et al. 2021), into practical affordances that align with the needs of service providers. To obtain these insights, multi-stakeholder interviews were conducted with domain experts. This research can, therefore, serve as a foundation for enhancing the adoption and implementation of DIS, ultimately empowering service providers to navigate the evolving landscape of data management with efficiency and effectiveness.

This paper begins with a literature review covering IT affordances, IT capabilities, interoperable and decentralized storage, the capabilities of Solid and the affordances of information systems in general, blockchain, and big data. Following the literature review, the [methodology](#) section outlines the research approach. The results section discusses the empirical findings concerning the affordances of DIS (e.g. Solid). The subsequent discussion section critically analyzes these results, comparing the affordances of DIS with the information system, big data and blockchain affordances. Finally, the paper concludes by synthesizing key takeaways and proposing practical applications for the insights gained from the study on IT affordances, DIS, and related technologies.

## 2 Theoretical background

### 2.1 Defining decentralized and interoperable data storage

Within the context of organizational governance, decentralization excludes the need for central authorities for the sharing of data (Trautwein et al. 2022). In the case of platform ownership, platforms can be centralized or decentralized, where decentralized platforms are governed by peer-to-peer communities, such as blockchain platforms (Hein et al. 2020). Furthermore, a growing body of literature addresses the decentralization of storage as an alternative to conventional cloud storage, where data are stored and managed by a third party (Khalid et al. 2023). This shift towards a network of nodes for data storage is driven by diminishing trust in cloud storage providers. In essence, decentralization of storage entails a method without central governing authority but rather a network of self-regulating storage nodes exchanging information.

Current research often suggests blockchain technology for decentralized storage, facilitating secure (internal and external) data sharing among various stakeholders (Hein et al. 2020). Blockchain's adaptability presents benefits in various industries (Rana et al. 2022; Stefanescu et al. 2023). For instance, in healthcare, it strengthens fraud detection and information completeness. In the context of Industry 4.0, distributed ledger technology simplifies the aggregation and processing of multiple hetero-

geneous data sources such as sensors. Furthermore, in eGovernance, it is applied to establish a citizen-centric model for public administration, promoting efficiency and user-friendliness (Domalis et al. 2021).

Besides blockchain, other technologies are also proposed for the decentralization of storage. The upcoming data spaces employ a distinctive approach to data storage and sharing using ‘federated, decentrally organized data space’ using connectors (Kremer et al. 2022). Data connectors are software components of the data space that allow peers (data providers and users) to set up agreements for data exchange from different sources within the data space following certain predefined rules of the data space. The European Data Spaces Support Centre characterizes a data space as “A distributed system defined by a governance framework that enables secure and trustworthy data transactions between participants while supporting trust and data sovereignty.” (Data Spaces Support Centre (DSSC) 2023). Different data spaces are already starting to become operational. These create various benefits for the data space participants such as process improvements or additional revenue through the introduction of services.

When systems become more decentralized (in terms of storage and control) this requires that they are still able to interact and thus are interoperable. In literature, interoperable systems for data sharing are discussed in terms of technical implementations (Bertocco et al. 2017; Fazio et al. 2015). Additionally, both industry stakeholders and policy makers propose interoperable building blocks or technical tools in order to facilitate interoperable data exchanges between stakeholders (Nagel et al. 2021). The European Commission (2017) defines interoperability in six different layers; Interoperability governance, Integrated public service governance, legal interoperability, organizational interoperability, semantic interoperability, and technical interoperability. Interoperability in the scope of this article only applies to two of those six layers, more specifically: (1) Technical interoperability: “This covers the applications and infrastructures linking systems and services. Aspects of technical interoperability include interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols.” (European Commission 2017, p. 32) (2) Semantic interoperability: “Semantic interoperability ensures that the precise format and meaning of exchanged data and information is preserved and understood throughout exchanges between parties, in other words ‘what is sent is what is understood’ (European commission 2017, p. 31).

When service providers adopt DIS, they often obtain access (based on certain legal ground or after consent is given) to large amounts of data. Big data analytics can rely on decentralized and interoperable data storage to efficiently access and process vast amounts of information distributed across multiple sources (Scerri et al. 2022). Interoperability enhances the accessibility of data by allowing different systems to seamlessly communicate and share information, facilitating more comprehensive analysis and insights from diverse datasets. Following this reasoning, big data analytics can be seen as a direct result of such storage solutions and is therefore a reliable domain. Big data analytics (BDA) refers to the analysis of data, where data are generated in large volumes and traditional data analysis techniques are not sufficient (Chamikara et al. 2019).

## 2.2 IT affordances and IT capabilities

An affordance is a concept originating from psychology that describes the relationship between an entity, its environment and the potential actions or behaviors it offers to a user (Gibson 2014). The concept has been widely applied in the field of Information Systems (Bansal and Shukla 2022; Carlo et al. 2012; Gal et al. 2014; Leonardi 2011), where affordances are not only properties of the IT system, but consists of the relationship between users and the technological features they interact with to achieve a business goal (Bansal and Shukla 2022; Treem and Leonardi 2013). An affordance thus shows how human beings use information technology (Chatterjee et al. 2020).

An important distinction exists between IT capabilities and IT affordances. The IT capabilities relate to the ‘materiality’, which are the objective properties of artifacts and natural objects rather than the interpretations or interventions of social actors (Robey et al. 2013). In contrast, IT affordances (Carlo et al. 2012) represent the recognized possibilities for goal-oriented actions within a specific user group. It is important to note that the same IT capability can lead to different affordances in various contexts due to the adaptability and negotiability of goal-oriented actions (Chatterjee et al. 2020). An example in the context of surfing the World Wide Web (an IT capability) is that one user uses it to be informed about the news while another uses it to communicate with his or her peers (affordance). Recent literature has emphasized the significance of considering the social dimensions of affordances alongside the predominant technological focus (Wang et al. 2018).

Within literature, various affordances within the broad field of information systems, big data analytics and blockchain are identified as shown in Table 1. The focus of this article was narrowed to identify areas related to decentralized and interoperable storage for service providers, including information systems in general and distributed ledger technology (e.g. blockchain) and big data analytics.

## 2.3 Capabilities of Solid

The Solid protocol builds on existing specifications (Capadisli et al. 2021). The purpose of this section is not to provide a full overview of the technological possibilities, but merely to provide insights into the capabilities that Solid could offer in combination with existing and/or new technologies. Within the remainder of this paragraph, the capabilities of Solid are further elaborated. This section provides the answer to what ‘decentralized and interoperable data storage solutions as provided by the Solid specification’ exactly means.

The first capability is the digital identity and representation of an agent. The authors will use the term agent for a person, organization or other entity as defined in the Solid protocol (Capadisli et al. 2021): “An agent is a person, social entity, or software identified by a URI, e.g., a WebID denotes an agent”. A WebID is an HTTP URI that points to a digital representation of an agent within Solid (Capadisli et al. 2021; Sambra et al. 2022). Based on this identifier, the agent is then able to authenticate (second capability) itself when there is no prior trust relation (Debackere et al. 2022). With Solid, authentication with third-party companies, e.g., Google or Facebook,

**Table 1** Overview of affordances for service providers concerning IS, blockchain and big data analytics identified in literature. An IT affordance shows how users can utilize an IT system. When comparing the three domains, we observe an overlap between the different affordances. For instance, the analytical affordance for blockchain and the data-driven process development affordance for BDA both include analyzing data to obtain insights

Affordance	Explanation	Domain	Literature
Organizational memory affordance	IT-facilitated ability to create, store, transform, refine, access, mobilize, apply, and exploit organizational knowledge	Information Systems	(Chatterjee et al. 2015, 2020)
Collaborative affordance	IT-facilitated ability to instill cooperation within an organization, both in a collocated and distributed/virtual settings, on a one-to-one or many-to-many basis	Information Systems	(Chatterjee et al. 2015, 2020)
Process management affordance	IT-facilitated ability to design, visualize, prioritize, and monitor work processes, as well as allocate and manage appropriate resources to enable action and decision	Information Systems	(Chatterjee et al. 2015, 2020)
Validity affordance	Ability to ensure the authenticity and correctness of transactions and data	Blockchain	(Spohrer and Risius 2022; Sun et al. 2022)
Analytical affordance	Ability to provide analytical insights and data-tracking functionalities	Blockchain	(Spohrer and Risius 2022)
Automation affordance	Ability to automate transactions and processes	Blockchain	(Du et al., 2019; Spohrer and Risius 2022)
Decentralization affordance	Ability to enable control of infrastructure, completion of tasks and decisions without a central authority (e.g. direct settlements of payment without banking authority)	Blockchain	(Du et al. 2019; Semenzin et al. 2022; Spohrer and Risius 2022)
Generative affordance	Ability to create new and/or innovate existing services	Blockchain	(Spohrer and Risius 2022)
Transparency affordance	Ability to increase transparency and trust in transactions	Blockchain	(Semenzin et al. 2022; Sun et al. 2022)
Security affordance	Data security through cryptographic techniques	Blockchain	(Sun et al. 2022)
Customer-centric marketing affordance	Ability to improve marketing effectiveness through personalized customer interactions	Big data analytics	(Dremel et al. 2020)
Data-driven services affordance	Ability to improve customer offerings through services that complement the core products.	Big data analytics	(Dremel et al. 2020; Liu et al. 2020; Zeng et al. 2020)
Data-driven process development affordance	Ability to analyze data to improve the functionality of existing products and services, establish feedback loops for future requirements and improvements	Big data analytics	(Dremel et al. 2020; Liu et al. 2020; Zeng et al. 2020)
Diagnostic affordance	Ability to leverage multiple data sources (e.g. sensor data) for optimization of production processes e.g. avoid downtime with real-time identification of failures	Big data analytics	(Dremel et al. 2020; Liu et al. 2020; Zeng et al. 2020)
Trust affordance	This affordance aims at leveraging products and sensor data to improve virtual collaboration and thereby increase trust in data quality	Big data analytics	(Liu et al. 2020)

is extended to authentication by other parties or the users themselves (Capadisli et al. 2021). An agent can grant or request access to pods, this includes authorization to add, edit, or remove data from a pod. For example, an agent can specify which identity providers to trust and which not. Additionally, Solid allows the capability for access control after authorization (third capability), providing the agent. This means it has the capability to provide the agent with an overview of existing access grants and the possibility to adjust them according to its preferences e.g., revoke access.

Data stored on a pod are structured as a collection of linked resources. According to the Solid specification, this makes it more convenient to discover data and links between data (Capadisli et al. 2021), making data findable using HTTP URIs (Berners-Lee 2006). However, there is no required format for data, meaning linked data as well as PDF files can be stored. In all cases, Solid offers the capability to add semantic meaning to the resource and make a resource machine-readable. The data are linked to other data and/or metadata. The linking of data and adding semantics are two different capabilities but both are very powerful building blocks to create an interoperable data-sharing ecosystem.

As opposed to storing data in a centralized database behind company walls, Solid allows to separate the storage of data from the applications. The data are stored in an interoperable and accessible manner (Werbrouck et al. 2021). In other words, the storage is 'decoupled' from the view on the data. Consequently, all parties will request authorization to access the data stored (as resources) on a Solid pod. Various options to interact with a resource on a pod exist: an agent can either remove, edit, or add a resource (read/write capability). When resources are accessed and altered by different agents, synchronization is important to avoid different versions of a resource. The Solid Notifications Protocol (Coburn and Capadisli 2021) enables agents to subscribe to resources, ensuring that when a resource is edited, all subscribed parties are informed, keeping all data up to date, and automatically notifying other parties when an agent alters a resource (synchronization capability).

Currently, the Solid documentation does not directly specify how an agent should discover data on a Solid pod. However, different approaches are suggested and both private and academic research is ongoing (Bogaerts et al. 2021; Collins et al. 2023; Solid Application Data Discovery Proposal 2018). Besides discovery, there is the capability to request specific questions (queries) that can be resolved. This way, discovery is included in the request for the data creating a more efficient process. In an early version of the Solid protocol, a SPARQL endpoint was included (Sambra et al. 2016) which allowed for querying on the Solid pod. Recently, others have also suggested adding query interfaces for Solid.

For different agents to exchange data and to trust that the data are correct, different mechanisms are proposed in literature (Dieltens 2021; Ramachandran et al. 2020). Verifiable credentials or smart contracts in combination with Solid, for example, can be a useful solution. The authors do not exclude that other possibilities exist, but this is outside the scope of this paper.

### 3 Methodology

First, to explore the capabilities and affordances of the Solid technology, multiple stakeholder interviews in an issue-focused stakeholder management approach (Roloff 2008) were performed. We employed a snowballing method to select interview subjects based on their interest in participating in the Flemish Solid personal data ecosystem (Berg 2006). The interviewees' roles in their companies and the Solid ecosystem can be found in Annex 1. The semi-structured interview method (Fontana and Frey 2000) was used, well-suited for the exploratory nature of this research (Adams 2015). This method offers flexibility with open-ended questions and allows for follow-up queries. Guidelines provided by Myers & Newman ensured interview validity, including the use of a topic guide featuring open questions regarding drivers and barriers in data sharing (Myers and Newman 2007) within a Solid ecosystem. The fundamental principles of decentralized and interoperable storage with Solid were explained, and the interviewees were asked which use cases and affordances they saw fit for their business. Since affordances represent the recognized possibilities for goal-oriented actions within a specific user group, this research focuses on the perspective of the service providers. Interviews were conducted in Dutch or English, and Dutch quotes were translated. We produced verbatim transcriptions, ensuring pseudonymization of the interview transcripts to establish trust. All interviews were conducted via Microsoft Teams and ranged from 1 to 1 h 45 min in duration. Based on the interview notes, the authors identified 75 potential use cases that interviewees perceived as potentially useful. A selection was made based on whether the use cases are possible with Solid, whether the use cases were described clearly and overlapping use cases were merged. A final selection of use cases amounted to 52 distinct use cases for service providers (See Table 2).

Second, we mapped the use cases on the capabilities of Solid. The affordances for service providers that were mentioned by the interviewees could be attributed to the required capabilities for the use cases. Axial coding, a mix of inductive and deductive thinking (Corbin and Strauss 2008), was used. Different factor tags were defined bottom-up, based on the affordance dimensions mentioned by the interviewees. The coding scheme is explained in Table 3; including the affordances, the capabilities, the benefits, and the number of interviewees that mentioned it. For each affordance, one example is provided. Section 4 provides an in-depth explanation of the affordances. Finally, the affordances mentioned in literature (for information systems, blockchain and big data analytics) were mapped on the Solid affordances. This serves as an additional contribution toward literature concerning IT affordances from the perspective of service providers.

**Table 2** An overview of the different interviewed companies and interviewees. There are three types of companies selected for the interviews; (1) Service Providers are companies that offer services to their customers and gather data to improve these services. (2) Technology providers provide technological solutions to other companies without gathering data. (3) Ecosystem Level organizations have a general role, looking at the innovation from an ecosystem perspective

Company	Role in Ecosystem	Role in company	Sector	Profile	Date Interview
1	Service Provider	Data management team	Finance	Content Expert	13/06/2022
2	Service Provider	Strategy and innovation	Finance	C-level	15/06/2022
3	Service Provider	Strategy and innovation	Human Resources	Content Expert	16/06/2022
4	Service Provider	Data strategy and projects	Media	Content Expert	14/07/2022
5	Service Provider	Innovation Manager	Media	Content Expert	28/06/2022
6	Service Provider	Senior Researcher	Media	Content Expert	04/11/2021
7	Technology provider	CEO	Technology	C-level	30/06/2021
8	Service Provider	Data and innovation	Human Resources	Content Expert	14/10/2021
9	Service Provider	Offering Manager	Mobility	Content Expert	10/11/2021
10	Service Provider	CEO and product owner	Human Resources	C-level	06/07/2022
11	Technology provider	CEO	Technology	C-level	07/07/2022
12	Ecosystem Level	Head data science lab	Health	Content Expert	12/07/2022
13	Technology provider	Business Development	Technology	Content Expert	13/07/2022
14	Ecosystem Level	Strategy	Energy	C-level	28/10/2021
15	Ecosystem Level	CEO	Telecommunication	C-level	15/10/2021
16	Service Provider	Product manager	Mobility	Content Expert	08/11/2021
17	Service Provider	Technical lead	Media	Content Expert	27/07/2022
18	Technology provider	CEO	Technology	C-level	28/07/2022
19	Technology provider	CTO	Technology	C-level	02/08/2022
20	Service Provider	Business consultant marketing and GDPR	Telecommunication	Content Expert	22/10/2022
21	Technology provider	CEO	Technology	C-level	04/08/2022
22	Service Provider	CEO	Health	C-level	08/08/2022
23	Service Provider	Chief Data Officer, business development	Media	Content Expert	10/08/2022
24	Technology provider	CTO	Technology	C-level	11/08/2022
25	Technology provider	CEO	Technology	C-level	07/09/2022

**Table 3** Explanation of coding tree used to analyze interviews in order to identify the different affordances. The affordances are enabled through different capabilities of Solid, this leads to different benefits for service providers (extracted from the interviews). For each affordance, one example is provided. Other examples are mentioned in the result Sect. 4 where the affordances are explained in depth

Affordance	Capability	Examples of consequences	Example of use case	Interviews
Transparency affordance	Authorization, access control, storage, linking of data, digital identity	Offering trust to end-users through open communication about data usage.	Simplifying consent management is often complex for a business. For instance, if the same data are required for multiple activities in different departments.	1,2,3,4,5,6,9,10,11,13,16,17,18,19,20,22,23,25
Personalization affordance	Linked data, semantic meaning, authorization, access control, digital identity, authentication	Improved user experience and -services e.g. enabling personalized advertising, personalized dashboards and recommendations	A bank advisor can see on a bank account that you pay a lot for heating, mobility, the gym... and identify that one component is out of scale. That way we would be able to say, 'Dear customer, your total cost of ownership of mobility is high, do you want to explore that?'	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,18,20,21,22,23,24,25
Automation affordance	Read/write, synchronization, storage, linking data, semantic meaning, authorization, digital identity	Simplification of processes, cost reductions (manhours)	Allow customers to complete actions with one click instead of having to confirm with all involved parties.	1,2,6,7,8,9,10,11,14,19,20,21,22,25
Collaboration affordance	Read/write, synchronization, storage, linking data, semantic meaning, querying, data discovery	Increase partnerships and data exchanges	When there is an accident, and a lot of parties have to charge their fee for reparations this can become very chaotic. If the data could be stored in a pod, this would simplify collaboration as all parties access the same documents in one storage space (pod).	1,2,3,4,5,6,7,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25
Interoperability affordance	Read/write, synchronization, storage, linking data, semantic meaning, querying, data discovery	To reduce redundant data sharing, IT and data management process costs	There are a lot of data-sharing platforms, however, they all still require manual input. These are often PDFs. This means that everything remains manual, if we could share the data instead of the documents, this would save a lot of time.	1,2,3,4,5,6,7,8,9,10,11,12,13,14,17,18,19,23,25
Decentralization affordance	Storage, authorization, access control, identity, authentication, read/Write	No longer reliant on third-party authentication or payments	Speeding up the authentication flow is valuable as this leads to more conversion. We tried to simplify the confirmation of owning a credit card. However, most solutions that offer this also require us to be locked into their data ecosystem. Solid could help us avoid this lock-in.	4,8,10,19,22,24

**Table 3** (continued)

Affordance	Capability	Examples of consequences	Example of use case	Interviews
Validity affordance	Verification e.g. credentials, linking of data and semantic meaning, digital identity	Simplification of processes, cost reductions (manhours)	Solid could allow verification of salary data if a credential is provided by the social secretaries. This way, a potential employer should not verify manually afterward, if the data provided by the employee is true.	1,2,3,4,8,9,21,24
Legalities affordance	Authorization, access control, digital identity, storage, authentication	Reduce liability and compliance costs	Solid could be a major enabler for being compliant with the GDPR and privacy management.	1,2,4,6,7,9,10,11,13,16,17,19,22,24,25

## 4 Results: affordances in decentralized and interoperable storage and the relation with its capabilities

In the result section, the different identified affordances from the interviews and their relation to the capabilities of Solid-based information systems are discussed. Secondly, the affordances from literature as summarized in Sect. 2.4 are compared with the affordances for DIS such as Solid.

### 4.1 Affordances

Through the interviews eight different affordances were identified and these are summarized in Table 3. Each of these affordances is discussed in depth within this section.

#### 4.1.1 Legalities affordance

Service providers recognize the crucial affordance of DIS in its ability to facilitate legal compliance. Notably, its alignment with European legislation on GDPR and the Data Governance Act affords service providers the opportunity to mitigate compliance and liability costs. By adopting DIS, service providers entrust a third party with the responsibility for secure and reliable storage, such as Solid pods. This delegation of storage, as mentioned by interviewees, has the potential to reduce compliance costs for service providers. Furthermore, the shift towards third-party hosting is viewed as a strategy to minimize the risk of errors, subsequently lowering the likelihood of fines from Data Protection Authorities (DPA). Service providers can request access to a Solid pod, contingent on the legal grounds necessitating data such as GDPR. This approach allows them to decrease their liability to the processing period rather than the storage duration.

#### 4.1.2 Transparency affordance

Transparency towards the end user was identified as a second valuable affordance. Service providers seek to enhance communication regarding consent and explore alternatives for cookies to capture end-user data. Nowadays, it is proven difficult for service providers to offer sufficient transparency toward end-users to establish a trust relationship. Furthermore, certain interviewees noted that increased transparency could also inform users on the utilization of their data and the advantages it brings to them. As a result, this information could induce their end-users to allow service providers to use the data. Since the data is no longer hidden, users obtain a transparent view on the data used as input for improving or personalizing services.

#### 4.1.3 Personalization affordance

DIS simplifies data sharing through the decoupling of storage and application. When sharing of data becomes easier, more user data becomes available. Since the data are also clustered together in a Solid pod, service providers are enabled to increase

the personalization of their offers through this data. This results in an increased user experience and improved services.

One example of personalization is enabling an agent to sign for a loan with one click, while in the background all required documents are shared with the right parties. Likewise, the amount of paperwork can be reduced when founding a business. Other examples of use cases using behavioral data from multiple sources, leading to adhering to user preferences and personalized advertisements. The additional benefit of not storing the data behind company walls is that user input can be requested to provide an additional feedback loop (e.g. users can remove or add preferences). The interviewees also believe that Solid can bring significant improvements to unburdening customers and simplifying the customer journey.

#### **4.1.4 4.1.4 Automation affordance**

DIS enables data sharing among diverse agents and thereby creates the possibility for process automation. Automation could increase the efficiency of administrative processes significantly. Examples were mentioned within the banking sector, human resource domain and governmental processes. For instance, the automated checking of solvability before a bank can extend a credit or automatic calculation of remunerations when switching jobs. Furthermore, several mentioned that errors can be reduced since the duplication of data is no longer required (except for backups for legal reasons). Furthermore, less effort is required to keep data up to date since it is stored in one place and accessible to multiple parties.

#### **4.1.5 Collaboration affordance**

By releasing data that were originally stuck behind company walls, new partnerships can be established. Different stakeholders can access the data in the same storage space, thereby streamlining collaborations. For instance, by combining data in strategic alliances (e.g. of a bank with a telecom provider) service providers can collaborate and develop a stronger market position. Moreover, service providers can keep or obtain new revenue streams by sharing data with third parties or using third-party data. By offering additional data services to others, e.g., by providing insights in aggregated purchasing data, or by selling access to data, they can generate new revenue streams. After a consultation, a doctor could share patient data efficiently with other players in the health ecosystem with consent of the patient. Thus, through the use of decentralized and interoperable storage, ecosystems are created that introduce diverse business opportunities and an improved customer service through collaboration.

#### **4.1.6 Interoperability affordance**

The interoperability affordance allows systems to interact and exchange information without having to implement complex integrations and investments. DIS (e.g. Solid) allows for more granular data sharing following open-source standards, which then allows for more efficient data sharing and data minimization. Before, complete

PDFs had to be shared, while Solid allows to access individual data points which are linked together. Since the standards are open source, all parties can implement them compared to proprietary standards. For example, the possibility to provide a bank with data about your income, housing conditions, and other data while the insurance company might only need very specific information regarding the requested loan. This example illustrates that both stakeholders' systems could become interoperable through Solid and how the data become interoperable in a way that digital agents can select only the required data points and nothing more.

#### 4.1.7 Decentralization affordance

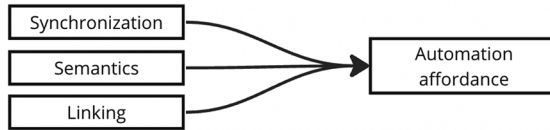
Since the data are no longer stuck behind company walls, multiple parties can make (re-)use of it. Additionally, Solid could mitigate vendor lock-ins through the affordance of decentralization as an additional consequence of the decoupling of data from applications. As mentioned for the personalization affordance, service providers attribute significant value to simplifying processes from an end-user perspective. For sign-up flows, this increases the lead-to-conversion ratio. For instance, a very intensive signup flow might result in consumers leaving before purchasing or ordering the service or product. They often outsource their processes to experienced companies. When this happens, the problem is that the service provider becomes part of the (often) closed and proprietary ecosystem of that third party. In other words, a vendor-lock-in occurs as data are highly controlled within the company borders. This also occurs for other processes, such as payment processes. However, due to the decoupling, or in other words the decentralization of storage, data are no longer locked into proprietary ecosystems.

#### 4.1.8 Validity affordance

This affordance focuses on ensuring data quality and authenticity including three types of use cases mentioned by the interviewees: validated data, verification of data and authentic sources of data. Validated data mean that certain actors, such as a user, a company, or a government, can improve data in the pod and validate whether their data are correct. This way, data can remain up to date and qualitative. Verification relates to the fact that data such as certifications, diplomas or creditworthiness can be verified by the original source, e.g., a government, a bank, or a university. This installs trust in the data in the ecosystem which is beneficial for Service Providers. As data can be combined and compared, it allows for cross-checking of facts e.g., fraud detection based on location. At last, an authentic source is the term used to refer to a set of data held by a body that has been appointed by a legal act to manage these data, which are authoritative in a particular area of competence. The authentic source is thus a legal source that ensures that data are correct and up to date (BOSA 2023).

Verification and validation of data, as well as using data of an authentic source, can drive benefits for service providers by reducing the effort to verify the quality and validity of the data. It can reduce and prevent risks of infringements and fraud. Additionally, access to verified data can simplify administrative processes, thus reducing costs since this is no longer a manual exercise. Last, new business models for provid-

**Fig. 1** The mapping of the synchronization capability and two different affordances, illustrating the one-to-many relationship between capabilities and affordances



**Fig. 2** To enable the automation affordance, multiple capabilities are required such as synchronization, semantics, linking and others. The combination of these Solid capabilities leads to the automation affordance illustrating this many-to-one relationship

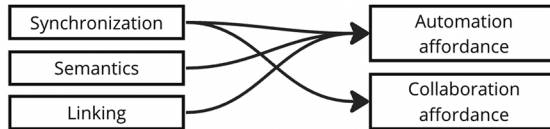
ers of authentic or original data could be created, as they can act as the original source of data and create revenues for providing access to the data.

## 4.2 Relationship between affordances and capabilities of solid

Literature suggests that out of one IT capability multiple IT affordances can arise in a one-to-many relationship (Chatterjee et al. 2020). This also holds for DIS (e.g. Solid), as illustrated in Fig. 1, since the synchronization capability brings forth both the collaboration and the automation affordance (among others, see Table 3 for a full overview). For the automation affordance, synchronization allows systems to automatically be aware of updates, thereby reducing the manual effort of keeping data up to date. For the collaboration affordance, synchronization allows service providers to be informed about changes of that data by others.

However, the capabilities of semantics and linking (among others, see Table 3) are also responsible for the automation affordance as they enable machine readable data. This many-to-one relationship is visualized in Fig. 2. Similarly, for the collaboration affordance, other capabilities are also required to make this possible. Thus, one affordance often results out of a combination of multiple capabilities (many-to-one). This illustrates the strength of Solid as the combination several standards and concepts, such as linked data, results into different opportunities that could not have manifested separately.

When integrating the insight that both one-to-many and many-to-one relationships between capabilities and affordances exist, it becomes apparent that, in the case of decentralized and interoperable storage, a many-to-many relationship between capabilities and affordances arises (see Fig. 3). A combination of capabilities leads to one or multiple affordances while simultaneously one capability (often in combination with others) can lead to different affordances.



**Fig. 3** The many-to-many relationship between capabilities and affordances as a result of multiple capabilities leading to one affordance and one capability leading to multiple affordances

## 5 Discussion: IT affordances of decentralized storage compared with affordances from literature

This article makes three key contributions to existing research. First, it contributes to the literature on affordances by comparing DIS (e.g. Solid) with information systems, blockchain, and BDA affordances. An overview of the mapping of the identified DIS affordances and the affordances mentioned in literature is presented in Table 4.

In comparison to affordance literature in **information systems** (Chatterjee et al. 2015, 2020), the identified affordances for DIS are similar to the collaborative and process management affordances in IS. The automation affordance of DIS (e.g. Solid) is reflected in the process management affordance of IS as it allows for collaboration concerning data sharing. The collaboration affordance of DIS also leads to new services through partnerships, similar to the collaborative affordance for IS. The automation affordance of DIS relates closely to the process management affordance of IS as it allows to optimize organizational processes e.g. streamline data collaborations and data sharing in general. The organizational memory affordance is less relevant in the case of DIS. However, as the three IS affordances are highly related (Chatterjee et al. 2015), the relationship between DIS and organizational memory affordance might be unidentified at the current stage since Solid is still in an early adoption phase.

Comparing the affordances of decentralized storage and interoperability with the affordances of **blockchain literature** (Du et al. 2019; Semenzin et al. 2022; Spohrer and Risius 2022; Sun et al. 2022), we observe a considerable overlap with DIS (e.g. Solid) affordances. The transparency affordance of DIS relates directly to the transparency affordance for blockchain. Second, the personalization affordance is related to the generative affordance for blockchain as it allows new customer-centric services. It also links with the automation affordance of blockchain. For the validity affordance there is great similarity with the validity affordance for blockchain as both rely on similar mechanisms such as verifiable credentials. However, blockchain also ensures the immutability of data, which is not the case for Solid. Although DIS technologies stand out due to their emphasis on the decentralization affordance and compliance with legislation, other affordances within blockchain-related technologies show similarities.

Concerning **big data analytics** (Dremel et al. 2020; Liu et al. 2020; Zeng et al. 2020), significant overlap with affordances for DIS (e.g. Solid) also exist in transparency, personalization, collaboration, and automation affordances. The BDA affordance of transparency relates to data-based trust since data can provide transparency regarding the state (e.g. financial) of other agents.

**Table 4** Mapping Solid affordances on IS, blockchain and BDA affordances (see Table 1) reveals that some Solid affordances relate to multiple affordances in the related domains, as some of these do overlap (see caption Table 1). The interoperability and legalities affordance apply exclusively for Solid. However, for blockchain it is reasonable to expect that the legalities affordance is applicable, given its connection to decentralization

Affordances for reliable domains	Information systems			Blockchain				Big Data					
	Organizational memory	Collaborative Process Management	Process Management	Validity	Analytical	Automation	Generative		Transparency	Decentralization	Customer-centric services marketing	Data-driven processes development	Diagnostic affordance
Affordances for decentralized & interoperable storage													
Transparency													x
Personalization												x	
Automation													
Collaboration													
Interoperability													
Decentralization													
Validity													
Legalities													

For two Solid affordances, the interoperability and legalities affordance, there appears to be no overlap with IS, blockchain or BDA affordances mentioned in literature. The interoperability affordance follows from the fact that the data are semantically enriched and linked. These capabilities are not present for the relatable domains. For the legalities affordance, one could reason that this also holds for blockchain as it also allows decoupled storage, however, this is not mentioned in literature to our knowledge. Thus, we can conclude that **affordances for on decentralized storage and interoperability differentiate from other technologies** through affordances such as interoperability and legalities affordances.

Two of the affordances identified in literature (organizational and analytical) are not identified for DIS. As mentioned, the organizational memory affordance relates to internal processes while DIS allow for cooperation outside of company walls. The analytical affordance is not identified either, as DIS relates to storage and sharing rather than to the analyzing and processing data.

Second, this work contributes to affordance theory applied in information systems (Chatterjee et al. 2015, 2020), as previous literature suggests that one IT capability can give rise to multiple IT affordances in a one-to-many relationship. Ultimately, in decentralized and interoperable storage systems, there exists a many-to-many relationship between capabilities and affordances, where a combination of capabilities can lead to one or multiple affordances, and a single capability can contribute to different affordances in conjunction with others.

Last, this research covers affordances from the perspective of service providers and thereby contributes to the body of the literature concerning decentralized and interoperable data storage as described in Sect. 2. Overall, the affordances identified within this research serve as a valuable starting point for service providers when evaluating decentralized and interoperable storage solutions. For instance, research on data spaces (Scerri et al. 2022) identifies several challenges for data spaces to tackle before value can be generated. One identified challenge is the lack of trustworthiness of data sharing ecosystems and data spaces. This type of storage solutions enables the transparency affordance which allows service providers to foster trust within ecosystems. Moreover, these affordances act as fundamental components for the implementation of big data and data enabled services (Dremel et al. 2020; Liu et al. 2020; Zeng et al. 2020; Scerri et al. 2022).

## **6 Conclusion: Decentralized and interoperable storage brings value towards service providers through a combination of capabilities**

The analysis has shown that decentralized and interoperable storage, in particular Solid-based implementations, brings value to service providers through many different affordances. This work goes beyond the state of the art of current research concerning Solid by structurally identifying capabilities and affordances utilizing the affordance theory from the perspective of service providers.

The analysis has shown that the value of decentralized and interoperable storage is not merely determined by individual capabilities, but through the combination of those capabilities and the potential impact for service providers. Different combina-

tions of capabilities result in various affordances for decentralized and interoperable storage. Thus, the same capability enables multiple affordances as it is combined with other capabilities (many-to-many relationship). These affordances can result in both cost reductions due to time efficiency of process simplifications, new revenue streams by introducing additional services as well as other more qualitative benefits, e.g., customer intimacy, for organizations through different affordances (see Table 3 for examples). Thus, most value is created through the combination of different capabilities. Finally, this paper contributes to affordances literature as it shows considerable overlap with the literature on affordances of IS, blockchain and BDA. It identified two additional affordances compared to existing literature on similar technologies, namely the legalities and interoperability affordance.

This study has one limitation related to the fact that Solid is a rather novel technology. For this reason, we had to first explain this concept to the interviewees thereby risking to introduce bias in their responses to our questions. Another limitation concerns potential restrictions regarding generalizability of our findings to other geographies as well as over time. This is a result of the exploratory nature of the research within the emerging Solid ecosystem in Flanders. This paper identifies two additional areas for future research. First, future research could explore whether other affordances are present for service providers and for other stakeholder's perspectives (e.g. end-users) as this paper focused on technologies in an early adoption phase. Further research could also focus on the potential comparison with other domains, for instance, personal information management systems (PIMS).

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