Leveraging the internet of behaviours and digital nudges for enhancing customers' financial decision-making

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Abstract: Human behaviour, which is led by the human, emotional and occasionally fallible brain, is highly influenced by the environment in which choices are presented. This research paper explores the synergistic potential of the Internet of Behaviours (IoB) and digital nudges in the financial sector as new avenues for intervention while shedding light on the IoB benefits and the digital nudges' added value in these financial settings. Afterward, it proposes an IoB-Nudges conceptual model to explain how these two concepts would be incorporated and investigates their complementary relationship and benefits for this sector. Finally, the paper also discusses key challenges to be addressed by the IoB framework.

Keywords: IoB; internet of behaviours; nudge theory; digital nudges; financial decision-making.

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1   Introduction

Customers in the financial sector are confronted with an overwhelming number of choices and decisions to make.

From selecting the right investment portfolio to managing personal finances, the complexity of financial decisions can be daunting. The consequences of these choices are significant, impacting individuals' financial well-being,

stability and prospects. Moreover, the financial sector faces unique challenges in promoting positive financial behaviours and empowering individuals to make sound financial decisions. In the contemporary business landscape, financial institutions are increasingly recognising the importance of Corporate Social Responsibility (CSR) in shaping their operations and interactions with customers (Angelini and Nieri, 2022). As part of their CSR strategies, financial institutions aim to not only achieve business objectives and provide innovative services but also contribute positively to society, thus building trust and credibility with stakeholders. In fact, customers are increasingly drawn to brands that align with their values and demonstrate a commitment to social responsibility; employees are increasingly seeking employers that prioritise CSR and offer opportunities to contribute to a meaningful cause; and investors are increasingly considering Environmental, Social and Governance (ESG) factors when making investment decisions. Thus, financial institutions with strong CSR commitments are viewed more favourably and can build resilience against reputational crises and negative publicity. To address such challenges, we explore an innovative approach that leverages the Internet of Behaviours (IoB) and digital nudges to empower customers and enhance decision-making in the financial realm.

Influencing or changing individuals' behaviour is crucial to solving some of today's most pressing societal challenges. However, how can this behaviour change be achieved? Recently, more and more researchers and policy makers have approached this question using choice architecture interventions, because traditional approaches, such as educational campaigns and disclosure requirements, have shown limitations in achieving long-term behaviour change (García and Vila, 2020; Dolan, et al., 2012; Smith, et al., 2020). Promote healthy choices through intentional application design and optimise how products or services are proposed can make the healthiest choice the easiest. For instance, by borrowing techniques utilised in the Well Building Standard personalising it for this sector, and implementing CSR and ESG frameworks, institutions would adhere to encouraging healthier lifestyle choices among their customers. However, the advent of Internet of Behaviours (IoB) and digital nudges offers new avenues for intervention, leveraging real-time data, personalised insights and contextualised nudges to influence consumer behaviour in a more targeted and effective manner.

The IoB is an ecosystem that uses data gathered from IoT devices or online platforms to monitor, analyse, predict and influence human behaviour. It is a framework that combines technologies such as Artificial Intelligence (AI), Machine Learning (ML), advanced edge analytics and behavioural science, and aims to predict, alter and influence individuals' behaviour or achieve automated decision-making (Elayan et al., 2023). The IoB can represent a paradigm shift in the way financial institutions collect and utilise consumer data. By harnessing data from various sources, such as mobile devices, wearables and online platforms, the IoB can enable a deeper understanding of individuals' financial behaviours, preferences and needs. This rich data ecosystem allows personalised experiences, tailored recommendations and real-time insights that empower consumers to make informed

financial decisions. By integrating IoB technologies, financial institutions can provide customised solutions, detect patterns and anticipate consumer needs, ultimately fostering better financial outcomes (Meng and Junfeng, 2019; OECD, 2021).

On the other hand, nudging is a behavioural intervention that focuses on creating choice environments that enable individually and socially beneficial decisions without limiting people's freedom of choice. It was the release of this book (Thaler and Sunstein, 2008) that widely introduced this intervention approach known as choice architecture, or nudging. Every day, humans encounter choices, but the outcome of every choice is determined not solely by logical assessments of the available options but also by the design of the choice environment in which information is provided, which can subconsciously impact the final result (Thaler and Sunstein, 2008). Nudges are prompts that use insights from behavioural economics to influence individuals' decision-making processes, gently steer consumers towards choices aligned with their long-term financial goals, and help people adopt a desired behaviour. By passively altering user interfaces to influence choices, digital nudging implements the concept of choice architecture (e.g., defaults, decision aids) in digital settings, utilising familiar technologies such as SMS, emails, push notifications, mobile apps and gamification. Nudges are two types (Kahneman, 2011), type 1 guides an individual's behaviour without him noticing it and is called 'System 1' nudges. And type 2, called 'System 2', requires people to make thoughtful decisions, mainly when influenced by easily manipulable elements like how a decision is framed.

In the financial realm, nudges can take many forms and can be impacted by different effects. Dolan et al. (2012) discussed in their review nine effects, they considered as the most efficient interventions for changing customers' behaviour in the financial sector, arranged as MINDSPACE, which stands for Messenger, Incentives, Norms, Defaults, Salience, Priming, Affect, Commitment and Ego, since 'what is chosen often depends upon how the choice is presented' (Johnson et al., 2012). There has been research that showed that people can be persuaded to make certain decisions and be nudged into acting in a certain way by making even little changes to the environment in which choices are presented for selection. Indeed, this research (Johnson and Goldstein, 2003) demonstrated that changing the default options for organ donation from opt-in to opt-out nearly doubled the number of people who agreed to be donors. Also, the mobile payment software Square intentionally encourages tipping by setting the default to 'tipping' and forcing users to deliberately pick the 'no tipping' option if they object. In areas where tipping is uncommon or non-existent, using this straightforward push has significantly increased tip amounts (Carr, 2013). Studies have also shown that personalised financial advice and nudges can positively impact decision-making and financial outcomes. For example, research (Benartzi and Thaler, 2013) demonstrated that digital nudges, such as reminders and goal-setting prompts, can significantly increase retirement savings rates. Thus, by embracing the possibilities offered by the IoB and digital nudges, financial institutions can foster a new era of customer-centricity, where

individuals are empowered to make informed financial decisions and achieve their long-term financial goals.

Financial institutions, through the IoB ecosystem, can gather and take advantage of valuable data on consumers' financial behaviours, preferences and needs. This data-driven approach will allow for the design and delivery of personalised experiences, tailored recommendations, and real-time insights to empower consumers towards making informed financial decisions and keeping focus on their financial goals. By embracing the potential of IoB and digital nudges, financial institutions can proactively engage consumers, foster financial literacy, encourage positive financial behaviours and facilitate more informed decision-making.

This research paper aims to delve into the synergistic potential of integrating IoB and digital nudges in the financial sector. It will examine how IoB can provide real-time insights, personalised recommendations, and behavioural feedback, while digital nudges can leverage these insights to influence decision-making, encourage positive financial behaviours and improve financial well-being.

The paper's content is structured as follows: we first offer a literature review to discuss papers and previous works related to our subject. Then, we present both the IoB and nudges benefits for the financial sector. Afterward, we examine the integration of IoB with nudges in the financial sector and explore the synergistic potential of adopting this approach, shedding light on their combined benefits and implications for customer behaviour and financial well-being. Thereafter, we present an IoB-Nudges conceptual model that showcases how these two technologies would be combined and serve the financial sector. Finally, we discuss the limitations to be considered by the IoB-Nudge framework.

This paper's contributions can be summarised as follows:

- To the best of our knowledge, this is the first attempt to investigate the concept of IoB while combined with Nudges in the financial sector.

- Thoroughly discuss the IoB concept in financial settings, its workflow, benefits and the challenges to be addressed.

- Extensively discuss the Nudge theory, digital nudges, their benefits and challenges to be handled.

- Explore the potential of integrating the IoB and Nudges in the financial sector.

- Propose an IoB-Nudges conceptual model that aims to influence consumers' behaviour and help them thrive financially.

2   Related work

García and Vila (2020) summarised the findings of an empirical study conducted with workers of a large Spanish life and pensions firm. The experiment's findings indicated that having financial knowledge of the necessity of saving is insufficient to motivate people to act. Despite pension plan specialists, a mix of two sorts of tools is required: logical tools, like being financially literate and understanding the fiscal consequences of retiring, and nudging, which motivates individuals to take meaningful action.

Mertens et al. (2022) offered through their paper a thorough examination of the efficiency of choice architecture interventions through methodologies, behavioural domains and contextual study variables. Additionally, they discovered that through behavioural domains, interventions that emphasise the structure of choice alternatives (decision structure) consistently outperform those that emphasise the description of alternatives (decision information) or the support of behavioural intentions (decision assistance). They stated that in general, choice architecture interventions influence behaviour somewhat independently of contextual research variables such as geographic location or intervention target population.

Franklin et al. (2019) discussed and directly compared the performance of two Behavioural interventions in the financial context, which are nudges and boosts. They conducted two studies in the USA and Serbia using both nudge and boost interventions to examine a sequence of decisions under incertitude. This paper provided light on extremely subtle, complicated patterns in population behaviour in the setting of financial choice under incertitude and showed significant implications for the design of interventions for policies that influence behaviour across populations.

Dolan et al. (2012) reviewed nudges interventions that are effective in changing behaviours in ways that enhance the financial capability and performance of individuals. They first examined the evidence for more traditional interventions focusing on improving financial competence through financial education and literacy targeted at changing minds. Then, they focused on what they consider the nine most potent contextual effects on behaviour, which are built on the framework known as MINDSPACE.

Kwok (2023) sought to study the interaction of behavioural psychology and emerging technologies in a hyper connected and data-driven society in his research. He examined IoB in the setting of tourism, as well as the development of the nudge theory in regards to the application of data for influencing behaviour when traveling. He also highlighted prospective scenarios for using IoB in smart tourism and framed an exchange of the social quandary it creates.

Rosa (2022) discussed the aim and the benefits of applying nudges in the banking sector, especially by the financial institutions to promote socially responsible investment. He discussed the bank of 'Banco Carregosa' as an example, examining that it used nudging techniques to gradually maximise discipline in investment, encourage investors to choose socially responsible investments in favour of traditional funds and to inculcate greener attitude among its clients. He stated that the bank implemented investor and investment profile questionnaires that could serve as the 'nudge' that leads clients to change their investments in accordance with their desired risk/return profile.

Furthermore, Moustati et al. (2023) also studied the IoB in other domains and different use-case scenarios. Moghaddam et al. (2022) utilised a conceptual model to

establish a socio-technical structure to monitor crowds and manage queues at the Uffizi Galleries in Florence, Italy. Lai et al. (2023) proposed an IoB strategy that utilised low-resolution, continuous thermal photography and advanced image processing techniques to enhance connectivity, data interchange and behavioural insights, which resulted in the creation of a respiratory rate measurement system that is more effective. Mezair et al. (2023) introduced an Advanced Deep Learning framework for IoB and used it in the context of connected automobiles. In another study Zhang et al. (2021), an IoB model is proposed to better analyse the relationship between air pollution and residents' everyday activities and see if and how differences in air pollution influence locals' everyday behaviours.

3 IoB and Nudges

3.1 The IoB's added value in finance

The Internet of Behaviours (IoB) can offer several benefits when applied to the finance sector. In this section, we will discuss ways in which it can greatly help.

3.1.1 Personalised financial services

Consumers' needs are becoming more diversified and tend to be personalised. Thus, banks must abandon the old single-sale model in favour of using computer and information technology to create personalised recommendations for budgeting and saving, and demand-oriented, separately priced and tailored customer-centric products and services. When having an IoB ecosystem, financial institutions can have access to a collection of extensive data on individuals' financial behaviours, preferences and needs, and can utilise different strategies to gather customer feedback. For instance, centralising surveys conducted within banking apps or online, social media monitoring by tracking mentions, comments and conversations related to their brand, products or services, behavioural analysis, emotion recognition and contextual intelligence analysis. When this data is analysed within the IoB framework, the system can gain a deeper understanding of individual preferences, inform credit scores, calculate interest rates and tailor services accordingly. Thus, financial institutions can improve their operational efficiency, and offer personalised investment advice, financial planning and product recommendations based on the specific needs and goals of each customer. Personalisation and precise customer service are a key factor for businesses to increase their profits and their customers' loyalty (Tong et al., 2012; Saleem, 2017). Financial institutions can create detailed customer profiles by gathering information about customers' demographics, financial behaviours, life stages, risk tolerance and sustainability levels and utilising goal-based planning to help customers define their goals. The system can also recommend goals, allow customers to readjust them and dynamically adapt these profiles over time to changes in their financial circumstances, goals and preferences. By incorporating customers' goals into the recommendation process and giving them control over their preferences, banks can ensure that personalised recommendations are aligned with their long-term objectives and reflect their individual preferences and comfort levels. Combining this with behavioural analysis, predictive analysis and DL models, financial institutions can generate insights into customers' preferences and sustainability engagement levels, anticipate their needs, offer relevant and timely recommendations and utilise this knowledge to optimise their nudging mechanisms.

Within the IoB ecosystem, financial institutions can leverage big data analytics and correlation analysis to analyse the optimal sales match, and mine the large amount of accumulated data for valuable information to build and train a customer accurate recommendation model that deeply understand customer needs, to achieve personalisation and develop new models of the financial industry and new businesses. Correlation analysis within the IoB involves collecting relevant behavioural data, selecting variables of interest, calculating correlation coefficients to quantify associations and interpreting the results. While hypothesis testing determines the statistical significance of observed correlations. Financial institutions can increase profits by expanding sales to existing customers, enhance corporate image and cultivate customer loyalty by also leveraging cross-selling, which is the marketing process that consists of providing new products and services to existing customers (Meng and Junfeng, 2019).

3.1.2 Fraud detection and prevention

The IoB can also play a significant role in helping financial institutions improve their fraud detection and prevention approach. First, by leveraging the wide range of behavioural data points generated through connected devices and digital platforms, including transaction histories, device interactions, browsing patterns and biometric data, IoB technologies enable advanced analytics and predictive models that can detect and mitigate fraudulent activities more effectively (Choi and Lee, 2018). The IoB ecosystem provides a holistic view of customers' digital behaviour and helps establish their baseline patterns for detecting any deviations that may indicate fraudulent activities. Moreover, AI models within the IoB framework can benefit and leverage the huge amount of behavioural data about customers' transactions patterns, spending and account management patterns available to tailor their classification mechanisms allowing the financial institutions to early detect and promptly identify and respond to potentially fraudulent activities. By analysing patterns and anomalies in real-time, unusual or suspicious transactions and activities can be flagged for further investigation, while triggering immediate alerts or interventions to prevent further damage. Furthermore, IoB technologies like data mining, and ML, enable the development of robust fraud detection models (Al-Hashedi and Magalingam, 2021). By analysing historical data and continuously learning from new behavioural patterns, these models can identify suspicious activities and adapt to evolving fraud schemes. As fraudsters continually

adapt and evolve their tactics, static fraud detection models may become outdated and less effective with time. By incorporating continuous learning mechanisms, such as machine learning and principally deep learning algorithms, fraud detection models can adapt in real-time to detect emerging fraud patterns and anomalies in consumer behaviour. This involves analysing new data as it becomes available, identifying new patterns indicative of fraudulent activity and updating the model accordingly. Financial institutions and FinTech lenders can use these IoB built-in technologies for fraud detection, client onboarding and KYC inspections, anti-money laundering and terrorist financing examination at these stages of customer due diligence. Through visual recognition programs, risk models and other AI-based techniques, IoB can assist institutions in recognising abnormal transactions and identifying suspicious and potentially fraudulent activities (such as the fraudulent use of personal data of clients, misrepresenting products/services and other scams). Visual recognition programs can track user interactions with digital banking platforms, ATMs and other channels to identify deviations or irregularities in transactional behaviour. It can verify the authenticity of checks' signatures or other financial documents. By comparing scanned signatures with known signatures on file, AI algorithms can detect any discrepancies or irregularities, flagging potentially fraudulent transactions for further investigation. Also, video surveillance cameras installed at ATMs can capture footage of customer transactions in real-time and analyse it to detect suspicious behaviours, such as card skimming devices, unauthorised access attempts, or if the person trying to use the card is not the original customer. Customers are occasionally brought in to submit identity documents, such as passports, driver's licenses or utility bills. AI can thus verify the authenticity of these documents by examining features such as watermarks and microprints. Additionally, AI when leveraging the great amount of behavioural data available within the IoB ecosystem, can lessen the number of false positives or refusal of legitimate transactions (such as a credit card payment that was mistakenly refused), thus increasing customer satisfaction (OECD, 2021; Choi and Lee, 2018).

3.1.3 Financial education and behavioural interventions

IoB can support financial education initiatives by providing real-time feedback and nudges to customers based on their financial behaviours. Thus, financial institutions can take advantage of an IoB ecosystem and adopt personalised feedback and nudges to promote positive financial behaviours and improve their customers' financial well-being and decision-making (García and Vila, 2020). By implementing and adding IoB to the financial institutions' IT ecosystem, they can gain efficiency and performance. They can offer 'just-in-time' personalised financial education at the appropriate 'teachable time' to guarantee the optimum achievable results.

IoB enables financial institutions to collect and analyse vast amounts of data related to individuals' financial behaviours, preferences and needs. This data can be leveraged to provide personalised financial education, tailoring content and interventions to specific individuals or customer segments. By understanding customers' financial goals, challenges and spending patterns, financial institutions can deliver relevant educational resources, such as budgeting tips, savings strategies or investment guidance, which are more likely to resonate with individuals and support their financial well-being. Besides, every time the IoB system detects that the client has diverged from his financial goals, it can suggest some personalised tips and prompt accurate reminders to assist him in getting back on track. Practically, it can send real-time pop-up notifications to remind him, e.g., when he approaches his daily limit, alerts for account balances, bill due dates or to celebrate the client's financial milestones. Personalised tips can be in our proposed system, within a special part of the mobile application or in contextual banners, including recommendations to reduce expenses, set spending limits for specific categories or prioritise essential expenses. For customers with debt, the IoB system would also suggest a tailored debt repayment plan and monitor their progression. Financial institutions can also generate personalised reports on customers' financial activities and suggest some books, studies, lectures or actions to enhance their financial literacy and commitment to their goals. Moreover, financial institutions can add, e.g., on their mobile banking applications charts of the customers' spending divided into categories so that they can keep visual track of their budget. Visual budget tracking is a good tool for personal finance management since it can impact spending behaviour by enhancing self-control, increasing saving intentions and reducing impulsive spending (Gathergood, 2012; Fraternali et al., 2019). Indeed, people tend to be more motivated by the fear of loss than the prospect of gain. Visual budget tracking aligns with principles of behavioural economics, such as salience and framing, and highlights the consequences of overspending or deviating from savings goals by visually representing the impact on one's financial well-being. Visualisation responds to SMART criteria and makes budget constraints more salient and tangible, leading individuals to perceive saving as a more attainable and rewarding goal and increasing motivation and commitment to achieving them (Kothakota and Kiss, 2020; Chy and Buadi, 2023). IoB can facilitate behavioural interventions aimed at influencing individuals' financial decisions and behaviours. By analysing behavioural data, financial institutions can identify patterns, biases and cognitive factors that impact decision-making. This knowledge can then be utilised to design interventions that nudge individuals towards more favourable financial behaviours. For example, timely, dynamic and personalised notifications, reminders or alerts can be sent to individuals to encourage savings, discourage impulsive spending or promote responsible credit card usage.

An IoB system can also utilise gamification techniques to engage individuals in financial education and encourage

positive financial behaviours. By leveraging data on individuals' financial activities and progress, financial institutions can develop interactive and personalised gamified experiences that educate individuals while making the learning process enjoyable and rewarding. The IoB data can be used to tailor gamified experiences that align with users' interests and motivations. For example, users may earn points or rewards for certain types of transactions or for achieving specific savings milestones. Progress bars, achievement levels, virtual rewards, interactive quizzes, simulations and tutorials within gamified experiences can motivate users to take positive financial actions and enhance their knowledge and confidence in making informed financial decisions. Thus, benefiting from both the advantages of IoB and Game-based tools that have been proven successful in engaging the recipient (Fraternali et al., 2019; Oliveira et al., 2023; Majuri et al., 2018).

3.1.4 Improved customer financial experience

Customers' expectations in the banking sector are increasing exponentially, just as in various other domains and financial services companies are aware of this fact and its implications. Indeed, they count on the customer experience to differentiate themselves and drive growth. A study showed that 64% of executives from financial services companies affirm that improving the customer experience is a top-five business priority (Harvard Business Review, 2021). Thus, financial institutions can leverage an IoB system to enhance customer experience since it can provide customers with personalised recommendations, streamlined processes and proactive support. Knihován (2020) revealed that one in every two customers expressed a desire for tailored financial advice from their banks responding to their specific circumstances, such as including analyses of spending habits and advice on how to manage money. While 64% indicated that they are interested in insurance premiums that are tied to their driving behaviour (like driving safely). Customers are increasingly demanding an exclusively tailored product from their financial institutions. The same study affirmed that customers desire more connectivity between digital and physical channels. Over 50% of those who participated in the poll expressed a desire for a fully omnichannel banking experience that would enable them to smoothly move between both digital and physical channels (Verhoef et al., 2015). Thus, an IoB ecosystem would be of great help when applied to this context, creating a totally engaging experience for customers. Leveraging IoB's gathered data, financial institutions can enhance the overall customer experience. They can analyse customer behaviour across various touchpoints to identify pain points and areas for improvement. This information can be used to develop personalised digital experiences, optimise user interfaces and provide better customer support, by employing strategies such as personalised financial planning, behavioural nudges and incentives, customised product offerings and predictive customer service to address pain points and enhance customer experiences. IoB-based interventions often target specific behavioural outcomes, such as increasing savings, reducing debt or improving financial literacy. Financial institutions can conduct behavioural analysis to assess changes in customer behaviour before and after implementing IoB interventions. Also, utilising A/B testing will allow them to compare the effectiveness of different IoB interventions by randomly assigning customers to different treatment groups. IoB data are comprehensive and granular enough to provide insights into both customer behaviour and financial outcomes. By measuring outcomes such as click-through rates, customer satisfaction scores, profitability and Return on Investment (ROI), institutions can identify which interventions are most effective in driving desired behaviours and financial outcomes.

3.1.5 Risk assessment and underwriting

IoB data can be used to assess risk and improve underwriting processes. By analysing behavioural data such as spending habits, online activities and social media interactions, financial institutions can gain insights into an individual's creditworthiness and make more accurate risk assessments (Ramanujam and Napoleon, 2021). This can streamline loan approval processes and enhance credit scoring models.

IoB built-in technologies such as AI models might lower the cost of credit underwriting and make loans available to 'thin file' customers, possibly increasing their financial inclusion. The application of AI can increase efficiency in data processing for the evaluation of potential borrowers' creditworthiness, improve the underwriting decision-making process and improve lending management for portfolios. It may also enable the supply of ratings for credit to 'unscored' consumers with little credit history, thus boosting real-economy financing (SMEs) and perhaps encouraging the financial integration of under-banked masses (OECD, 2021). Furthermore, the application of AI approaches in blockchain-enabled finance might increase the potential efficiency advantages in Distributed Ledger Technology (DLT)-based systems and extend the potential of smart contracts. Indeed, integrating AI into DLT-based systems can improve smart contract automation, reduce but not eliminate security vulnerabilities, protect against network compromise and provide a wallet address analysis result that can be used for regulatory compliance or internal risk-based assessment of transaction parties (Chen et al., 2020). Also, it can enhance the functionality of third-party off-chain nodes, like 'Oracles', by validating the authenticity and integrity of the data they offer and preventing cyber-attacks or manipulating such third-party data supply into the network. Behavioural-data-enhanced ML models can improve smart contract autonomy by allowing the source code to be dynamically modified in response to market conditions and identify code flaws in smart contracts (OECD, 2021). However, modifying smart contract codes dynamically based on behavioural data could raise concerns regarding compliance with existing regulations. Regulatory bodies may require strict adherence to predetermined contract terms to ensure transparency, fairness and legal enforceability. Any modifications made to the smart contract code must comply with regulatory requirements to avoid potential legal ramifications, and be transparently

documented and auditable to ensure accountability and regulatory compliance.

The IoB framework can provide financial institutions with, among others, the abundance of real-time behavioural data, superior inexpensive processing capacity and enhanced ML models required for facilitating critical operations such as asset management, algorithmic trading, credit underwriting and blockchain-based services. When the IoB ecosystem advances, it may also be able to predict future financial crises based on behavioural data.

3.1.6 Compliance and regulatory requirements

The IoB can assist financial institutions in meeting compliance and regulatory requirements. By monitoring customer behaviour, institutions can identify potential risks related to money laundering, market manipulation or insider trading. This data can be used to strengthen compliance frameworks and ensure adherence to relevant regulations. Financial institutions can utilise IoB with RegTech to avoid misconduct by moving the emphasis from ex-post resolution to proactive prevention (OECD, 2021). An IoB system would enable financial institutions to collect and analyse vast amounts of behavioural data in real-time, which can be used to monitor customer behaviour, historical records, transactions and interactions across various digital channels. By employing IoB built-in technologies such as advanced analytics and machine learning algorithms, financial institutions can promptly detect suspicious activities, such as money laundering, fraud or insider trading. Real-time monitoring helps identify and address potential compliance breaches promptly, reducing the risk of regulatory violations and predictive analytics models can help identify areas that may require additional compliance measures, enabling proactive risk mitigation strategies. Moreover, through an IoB ecosystem, financial institutions can automate compliance reporting processes, simplifying the generation and submission of regulatory reports. By integrating IoB data with compliance systems, financial institutions can streamline the reporting requirements, ensuring accurate and timely submissions. Additionally, IoB can facilitate the creation of audit trails, providing a transparent and traceable record of activities and transactions, which is crucial for compliance audits and investigations.

3.1.7 Enhanced financial well-being, planning and budgeting

IoB can facilitate better financial planning and budgeting by tracking and analysing individuals' financial behaviours in real-time. Through behavioural data, IoB can psychologically understand the customers' income, expenses, saving patterns and investment behaviour. With this information, leveraging data-driven insights, financial institutions can offer tailored financial planning advice and strategies that align with individuals' goals and circumstances.

Financial institutions can utilise digital tools to leverage insights to enhance budgeting and saving habits. They can use smartphone apps in promoting saving behaviours and improving financial well-being, e.g., adding to their mobile application functionalities that provide customers with up-to-date information about their financial status and showcase their spending by categories. Besides adding visual charts that demonstrate how far they are from reaching their financial goal. This real-time monitoring helps individuals stay informed about their financial health, enabling them to make timely adjustments to their budget and spending decisions, besides being more financially aware and able to control their spending behaviour (French et al., 2021; Fraternali et al., 2019). Financial institutions can use IoB to recommend to customers the best appropriate products to invest in and provide them with real-time alerts and reminders to encourage them to have long-term investing goals. Having applications that continually alert customers when they diverge from their preset financial goals, advise, encourage and support them through their journey would certainly increase their financial performance while also increasing their loyalty to the financial institution (French et al., 2020). Cognitive bias can exert a profound influence on people's decision-making process within a particular choice environment by affecting how they perceive information, assess risks, employ decision-making heuristics, respond to emotions and interact with their social and environmental surroundings. This impact can be seen in different scenarios, e.g., the effect of confirmation bias on investment decisions, the anchoring bias in negotiations (the price tag effect) and the overconfidence bias causing financial losses (Kim et al., 2021; Bagatini et al., 2019). Based on the analysed behavioural data, financial institutions can show notifications or give personalised tutorials to their customers about some financial cognitive biases, such as mental accounting (Thaler, 1999), that may harm their financial health and impact their financial decision-making, to make them aware of and thus know the right way how to deal with it.

Below, in Figure 1, an overview of the potential effect the IoB may have in certain financial market operations, such as managing assets, trading, lending and blockchain applications in finance (OECD, 2021).

Figure 1 Examples of IoB's applications in certain financial operations (see online version for colours)
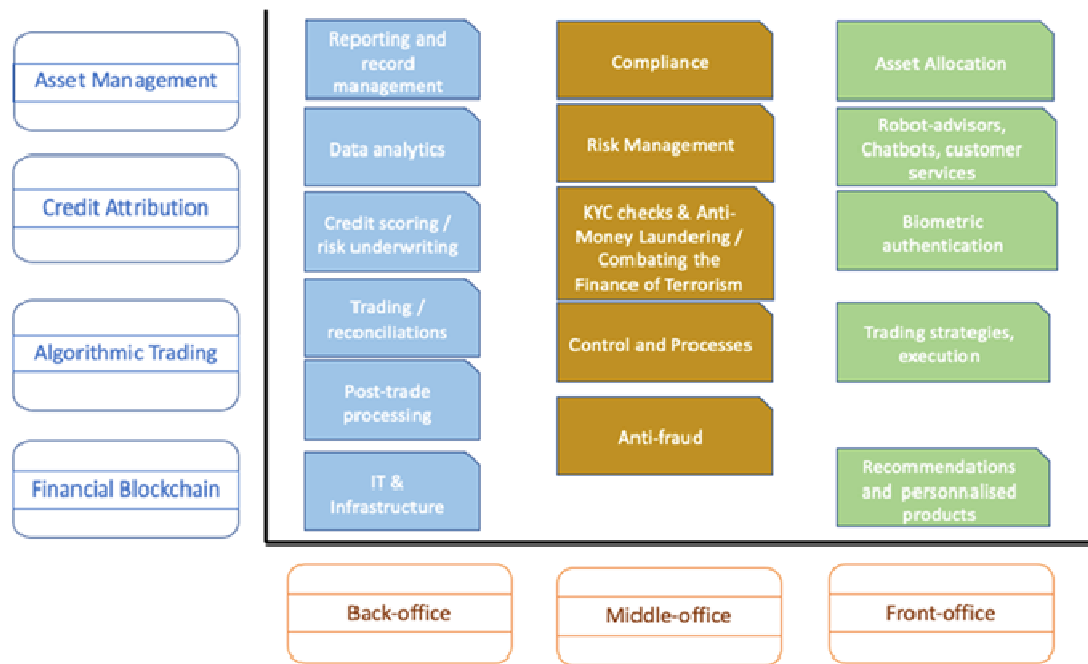
3.2 Nudges' added value to finance

Financial institutions can and should take advantage of IoB benefits to promote personalised financial literacy, e.g., through their mobile applications, since a lack of awareness of finance concepts and practices like saving and investing, along with a lack of appropriate counsel, leads to non-recommended investment choices and incurring risks without fully comprehending them. However, can financial literacy be efficient in the presence of poor cognitive and emotional control? Financial education aims to improve customers' financial literacy. However, it is unknown if it is capable of influencing their behaviour and motivating them to take action (García and Vila, 2020). Financial education alone does not appear to be sufficient to motivate people to act. Hence, additional sorts of interventions are needed to enhance healthy financial habits like appropriate investing and long-term saving practices. Therefore, nudging is required all along with financial knowledge to encourage behaviour that rational reasoning has failed to result in Cai (2020). Information and financial literacy might be helpful when action is under cognitive control, but they might be ineffective for procrastination-prone behaviours like raising long-term weak-intention-driven savings. However, it has been shown that appropriate behavioural interventions can enhance healthy financial behaviour even among financial industry experts and professionals (García and Vila, 2020). Nudges can help stop customers from making judgments only based on intuition or past behaviour when presented with complex options, as is the case when investing. Indeed, lack of access to personalised financial advice and guidance; limited knowledge or understanding of financial concepts, investment products and market dynamics; emotional biases such as fear, greed, overconfidence and loss aversion; behavioural biases like confirmation bias, anchoring bias and

hindsight bias and the complexity of investment products for novices are all challenges for them.

3.3 IoB and Nudges: a complementary relationship

The aim of targeted nudges in our lives, environments, habits and processes is to achieve better decisions and outcomes (Thaler and Sunstein, 2008). A nudge is a strategy for assisting individuals in achieving goals they keep in mind but still haven't taken action to attain, and a class of behavioural interventions that focus on the creation of decision-making settings that encourage individually and socially beneficial choices without limiting people's freedom of choice. While the IoB aims to leverage behavioural data, technology and behavioural psychology to first understand and then alter or influence customers' behaviours. Thus, when combining the IoB technologies and techniques with nudge interventions financial institutions can have more accurate and relevant targeted nudges, hence better results can be achieved. Nudge interventions can be implemented as techniques at the end of the IoB workflow (Sun et al., 2022) to influence and alter customers' behaviours effectively. Furthermore, financial institutions through nudges seek to get customers to take action on their desired goals, and they can leverage the IoB to reveal customers' intentions (Zhao et al., 2023). IoB can help accurately predict customers' intentions, goals, and what they aspire to achieve, thanks to applying technologies such as Deep Learning algorithms to behavioural data, thus extracting relevant, useful and real-time insights. The IoB can predict customers' intentions and help determine which nudges are more efficient by extensively analysing the gathered behavioural data, which contain information about customers' patterns and behaviours while interacting with the different nudges utilised by financial institutions. Once this data is analysed and interpreted, it can serve as a gold mine of

insights and can be utilised to enhance their nudge intervention strategies, hence the customers' experience. When integrating the IoB with nudges, several strategies can be employed to enhance the effectiveness of this ecosystem. Digital nudges would be tailored and personalised and suggest real-time tips based on the customer's circumstances. For example, when the system detects that the customer is overspending on dining out, it can trigger nudges that suggest effective budgeting techniques and present visual charts and illustrations to highlight the difference between the amount spent on meals out and the equivalent amount if he cooked at home. The system would also, i.e., suggest beneficial investments that could have been used with the remainder to emphasise the impact. Contextualised nudges can also be beneficial as reminders. When a customer travels abroad, a contextual nudge could remind him to notify their bank to prevent transaction declines. Social nudges would also be profitable since they could highlight social norms or peer comparisons. For example, if a consumer's social network is saving for retirement, a social nudge could emphasise the importance of retirement planning and showcase the positive outcomes achieved by his peers. Moreover, IoB behavioural data can inform the design of choice architectures by identifying decision points where nudges can be most effective. For example, if IoB data reveals that consumers often struggle with credit card debt, the choice architecture could be designed to promote responsible credit card usage through nudges and prompts. The complementary relationship between IoB and Nudges can be seen as a reflection loop, in which customers can reflect on their financial behaviours, and the IoB system can reflect on whether or not the implemented nudges are efficient.
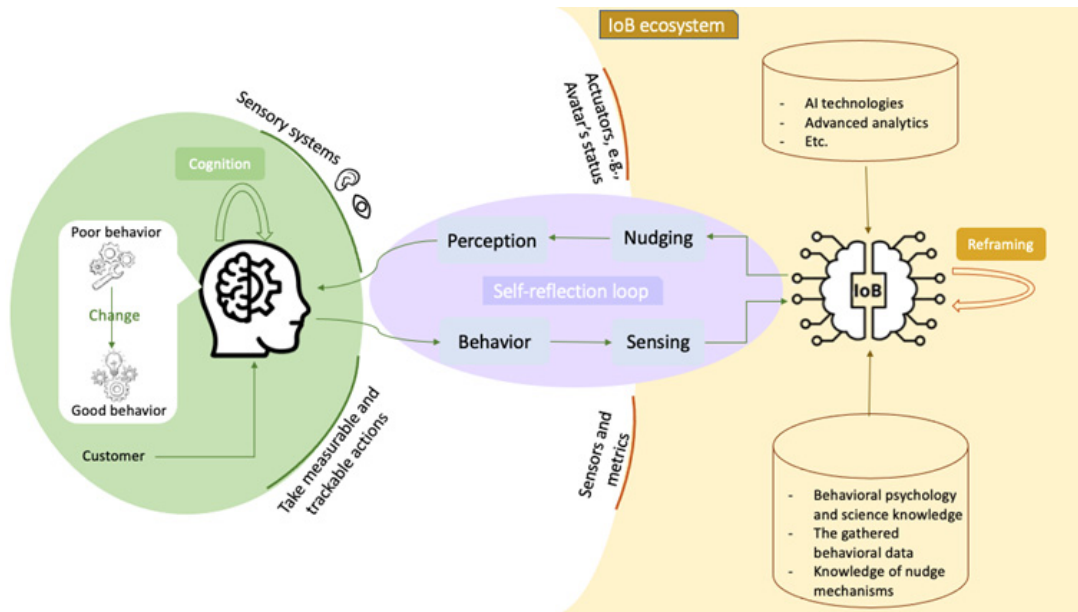
4   The IoB-Nudges conceptual model

Nudges can be efficiently built to reduce common impediments to saving, repaying debt and financial planning, with low or no attention required. Financial institutions can utilise clever approaches that employ rewards to drive customers' desire to engage in things they may not want to do, or they still procrastinate, but that yield long-term benefits for individuals and society. We propose in this section the IoB-Nudges model shown in Figure 2. A conceptual model that aims to establish a self-reflection loop in which the client's daily actions are captured by either an IoT device or through his online activities or metrics within the financial institution application. Then, based on this gathered behavioural data, the IoB system alters an element of the choice architecture, e.g., an avatar's state (that shows emotions based on customers' financial performance and the compliance level with their established strategy and financial goals). These alterations in the graphical representation of an actuator playfully encourage users to become more self-aware about their targeted behaviour and nudge them toward sticking to their established plans. An actuator can take many

forms, such as an avatar of customers represented on their smartwatch, band or even their mobile application icon, that shows the human emotional state through facial expressions. These emotional states can be analogue to their financial progress toward their defined goal, and customers will reflect on their daily behaviours when seeing it. The proposed model has key strengths and can achieve high adaptability performances. It utilises real-time data processing, advanced analysis and predictive analytics capabilities to continuously learn from data, quickly identify and respond to changes in user behaviour, and adapt its nudging strategies and recommendations for optimum results. The IoB system leverages contextual information to deliver personalised and relevant experiences, and actuators within it will dynamically adjust based on user preferences, behaviour history and situational context. It incorporates user feedback and performance metrics to iteratively improve its services, ensuring alignment with user expectations and preferences. The IoB ecosystem must employ scalable infrastructure and cloud-based services to accommodate growth and handle fluctuations in load and adopt a modular architecture that allows for easy integration of new components, functionalities and services.

The IoB facilitates collecting feedback on customers' financial behaviours, which can be used to provide ongoing feedback and learning opportunities. Digital nudges can leverage these feedback loops to help customers understand the consequences of their decisions, reinforce positive behaviours and encourage learning and self-correction. The IoB-Nudges workflow (see Figure 3) can be summarised in the following repeatable steps:

- Automatically tracking and collecting the customer's lifestyle habits through IoT sensors, online activity or the processed financial data available through the financial institutions' mobile or web applications.

- Analysing the data to extract useful information, and assess customers' level of commitment to their established financial goals.

- Processing and mining information to reveal patterns. Then, applying AI technologies and algorithms, and behavioural psychology to determine how these patterns affect customers' decisions.

- Concluding insights into the customer's compliance with his preset financial goals and strategies, revealing and predicting the customer's intention and deciding on the optimum nudge strategy to use henceforth.

- Providing real-time personalised feedback and playfully alternating the state of choice architecture's actuators to promote self-reflection and improve lifestyle habits. Thus, altering and influencing customers' decisions.

- Observe and assess the customer's reaction to the provided nudge through tracking his behaviours and restarting the process above.

Figure 2 The IoB-Nudges conceptual model (see online version for colours)

The proposed IoB conceptual model is composed of multiple components. The first component is the human side, in which we represented the customer as a conscious client that uses his sensory systems to interact with the IoB-nudges ecosystem. In our case, he will mainly use his sense of sight and hearing to remark changes in the actuator of the framework (avatar's status and the mobile application interactions), then he will involve his cognition and reflect on his recent financial behaviour. This self-reflection action will give him awareness on his financial behaviour and make him willing to changing his poor behaviour into a better one. Thus, he will take action that the ecosystem will measure and track through either IoT sensors (cameras, location trackers, etc.) or metrics gathered from mobile/web applications and financial transactions. In addition to the human component, actuators and sensors, there is the IoB framework, which consists of the system intelligence. In this component, we have an automatic system that utilises Advanced analytics (e.g., time series analysis, regression analysis), AI technologies (e.g., XAI, DL algorithms such as LSTM and CNN), behavioural science and behavioural psychology knowledge, nudges techniques and advanced technology

technicity (edge computing, 5G/6G, big data, etc.). All these components have a harmonised communication and interact continually in what we called a self-reflection loop, in which the customer update his behaviour and also the IoB system readjust its mechanisms based on it, to affect and influence the customer in the most efficient manner. Technologies that would be utilised in the implementation of such an ecosystem include but are not limited to Deep Learning algorithms such as LSTM, CNN and GCNN (Mezair et al., 2023) predicting future behaviour and extracting value from data and NoSQL databases (e.g., document-oriented databases like MongoDB) for storing the gathered behavioural data that would be shared in the cloud to support the massive number of real-time streams in unstructured or semi-structured formats. Also, adopting XAI frameworks like IBM AI Explainability 360 into the system will give explanations for different user concerns, provide them with an enhanced understanding of how the system works, and increase awareness of its impact. Thus, avoiding resistance and increasing trust and the system's impact. Other technologies, such as 5G/6G, Human-Computer Interaction (HCI) and edge computing (Moustati et al., 2023) would also serve the application of this IoB ecosystem.

Figure 3 IoB-Nudges workflow (see online version for colours)
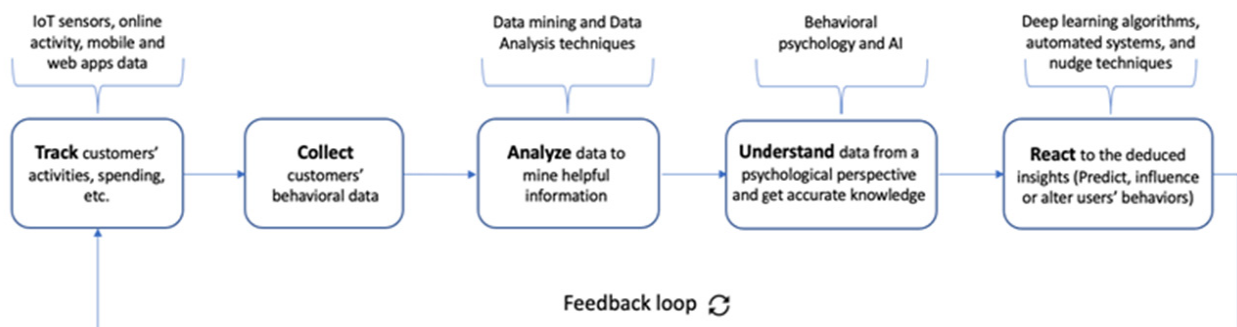
Through building an IoB-Nudges system, financial institutions can leverage the analysed behavioural data and the revealed accurate digital nudges interventions to incite customers to stick to their financial planned strategies, hence supporting them through their journey to achieving the results they aspired for and consequently increasing their self-confidence and their loyalty to the bank. Recently, rating agencies are increasingly giving corporations better credit scores based not only on their financial records, but also on their environmental, social and governance practices. Thus, banks can push clients toward adopting their CSR strategy. Financial institutions can leverage this system to create nudging mechanisms to encourage customers to invest in the stock of firms whose policies are shifting toward being backed by ESG or in funds that invest in corporations with comparable sustainability objectives in favour of traditional funds. Behavioural economics research has shown that individuals often make irrational or suboptimal financial decisions due to cognitive biases, emotions and social influences (Brahmana et al., 2012). By incorporating behavioural nudges derived from behavioural economics principles into the IoB ecosystem, financial institutions can influence user behaviour in positive ways, nudging them towards desirable financial actions and outcomes. Tailored nudges that resonate with individual preferences, goals and circumstances are more likely to capture attention, evoke engagement and drive behaviour change. Providing proactive, personalised financial guidance and support fosters a deeper sense of trust, loyalty and engagement between customers and financial institutions, and by delivering value-added services beyond traditional banking products, they can differentiate themselves in the competitive landscape and strengthen customer relationships. Financial institutions can utilise digital nudges in their mobile applications. These applications, being part of the IoB ecosystem, can help analyse customers' spending patterns, calculate the amount to set aside and transfer surplus funds automatically to the customer savings account or stock market account. Nudges can include enrolling customers automatically, unless they object, into plans of rounding up and transferring change on every purchase into a saving account or funnel raises directly into a savings account. Applications can leverage the IoB system to offer also anonymous information about the average amount other people in similar financial situations save to increase customers' own savings rate, daily inform customers about common setbacks investors face and how they can diversify their portfolio, encourage them to keep the discipline to avoid loses and recommend the best products to invest in.

5   Scope for enhancement

While applying the IoB in the finance sector with the Nudge theory can offer various benefits, there are also some limitations to consider. The use of digital nudges in financial decision-making raises ethical considerations. Nudges are designed to influence individuals' behaviour subtly, and there is a fine line between helpful guidance and manipulative practices. Financial institutions must use nudges responsibly and transparently, ensuring that individuals retain their autonomy and are not coerced into making decisions against their best interests. Because when nudges are misused, customers can be persuaded to spend much more than necessary or to make less-than-ideal investment decisions. Also, the effectiveness of nudges may vary across individuals due to differences in financial knowledge, preferences and cultural backgrounds. What works for one person may not work for another. It is crucial to benefit from the IoB to consider the diversity of individuals' needs and tailor nudges accordingly to maximise their effectiveness. The IoB serves in a challenging legal and regulatory environment, with challenges with data privacy, security, consent, intellectual property and accountability. Adherence with applicable legislation and regulations, as well as managing legal challenges, are continuous issues for IoB deployments. Ensuring privacy is a crucial phase in adopting an IoB ecosystem. Therefore, financial institutions must ensure robust security measures to safeguard consumer data against unauthorised access, breaches or cyber-attacks and maintain transparency about data collection and usage practices. Consumers should be fully informed about the types of data collected, how it will be used and the purposes for which it will be utilised. In the IoB realm, security and privacy have key implications (Almashaqbeh and Solomon, 2022), and data must be protected through the whole process chain. In data collection, a classic data aggregation technique, known as aggregator-oblivious encryption can be used (Shi et al., 2011), while the Data Transfer Project (DTP) can be used when transferring data (Team, 2018). To securely share data, we can implement a blockchain-like framework (Zhang and Zhou, 2020; Zhao et al., 2023). Data control can for example be implemented in a decentralised way through the Solid project (Team, 2021) or in a centralised manner through MyData project (M.G. Organisation, 2020). Additionally, datasets used for training must be large enough to capture non-linear relationships and tail events in the data, and the IoB built-in technologies like AI-driven models can inadvertently generate or perpetuate biases. It can also make credit allocation discrimination even more difficult to discover and model outputs difficult to comprehend and explain to refused prospective borrowers due to the lack of the interpretability of AI decision-making mechanisms. Thus, the IoB should emphasise using Explainable AI (XAI) to overcome the black-box issue of AI models (Arrieta et al., 2020). XAI can define the AI model's aim, rules and decision-making process so that the IoB framework users can comprehend how it operates. Furthermore, while nudges can be effective in promoting positive financial behaviours, there is a risk of individuals becoming overly reliant on them. If individuals solely depend on nudges for decision-making, they may not develop a deeper understanding of financial concepts or develop long-term financial management skills. Financial institutions should strike a balance between nudges and promoting financial literacy and empowerment. Moreover, sustaining the effects of nudges interventions

under the IoB ecosystem over the long term can be challenging. Individuals may revert to old habits once the nudges are removed, limiting the long-term impact on financial behaviour. Ensuring ongoing support, reinforcement and opportunities for learning and self-efficacy are crucial to promote sustained behavioural change.

It is crucial to recognise these limitations and address them appropriately to ensure the responsible and effective implementation of the Nudge theory under the IoB context in the finance sector. By doing so, financial institutions can leverage the benefits while mitigating the potential drawbacks.

6 Conclusions

Every day, people have to make decisions. However, human decisions are strongly influenced by the design of the choice environment in which the information is provided, and, mainly in the financial landscape, the cost of not making appropriate decisions can significantly affect individuals and societies. At present, by embracing the possibilities offered by the IoB and digital nudges, financial institutions can foster a new era of customer-centricity, where individuals are empowered to make informed financial decisions and achieve their long-term financial goals. The IoB will allow financial institutions to monitor the effectiveness of nudges and their impact on customer decision-making. By continuously evaluating and refining the nudges, institutions can adapt their strategies to maximise effectiveness and improve customer outcomes. Concretely, by implementing an IoB-nudges framework, financial institutions would, among other things, be able to cluster customers based on their behavioural patterns and create new innovative products that will fit each cluster, tailor financial contracts based on these insights, and provide more flexible payment options or automated savings features. Also, by continuously monitoring customer behaviours and transaction patterns, financial institutions can quickly detect unusual or suspicious activities and intervene proactively to prevent fraudulent transactions or identity theft. Digital nudges can be crucial in advising customers on security best practices, delivering influential educational content, helping customers attain their desired financial objectives and effectively pushing customers toward optimum financial behaviour.

This paper is the first attempt to investigate the concept of IoB while combined with Nudges in the financial sector. It has also proposed an IoB-Nudges conceptual model that showcases how these concepts would be integrated and implemented in financial settings. We extensively discussed how the IoB would benefit financial institutions, explained its workflow and delved into Nudges' added value in this sector. This paper explored the complementary relationship between those two concepts, showcased their incorporation and discussed challenges to consider when applying them.

References

Al-Hashedi, K.G. and Magalingam, P. (2019) 'Financial fraud detection applying data mining techniques: a comprehensive review from 2009 to 2019', *Computer Science Review*, Vol. 40. Doi: 10.1016/j.cosrev.2021.100402.

Almashaqbeh, G. and Solomon, R. (2022) 'Sok:privacy-preservingcomputing in the blockchain era', *Proceedings of the IEEE 7th European Symposium on Security and Privacy (EuroS&P)*, IEEE, pp.124–139.

Angelini, A. and Nieri, F. (2022) 'Corporate social responsibility in the banking industry: an overview', *Managing Sustainability*, pp.57–75. Doi: 10.1007/978-3-031-12027-5_4.

Arrieta, A.B. et al. (2020) 'Explainable artificial intelligence (XAI): concepts, taxonomies, opportunities and challenges toward responsible AI', *Information Fusion*, Vol. 58, pp.82–115. Doi: 10.1016/j.inffus.2019.12.012.

Bagatini, F.Z., Wagner, R.L. and Rech, E. (2019) 'The effects of a price tag presentation on the purchase intention of new products', *Congresso Latino-Americano de Varejo e Consumo*.

Benartzi, S. and Thaler, R.H. (2013) 'Behavioral economics and the retirement savings crisis', *Science (1979)*, Vol. 339, No. 6124, pp.1152–1153. Doi: 10.1126/science.1231320.

Brahmana, R.K., Hooy, C. and Ahmad, Z. (2012) 'Psychological factors on irrational financial decision making: case of day of the week anomaly', *Humanomics*, Vol. 28, No. 4, pp.236–257. Doi: 10.1108/08288661211277317.

Cai, C.W. (2020) 'Nudging the financial market? A review of the nudge theory', *Accounting and Finance*, Vol. 60, No. 4, pp.3341–3365. Doi: 10.1111/acfi.12471.

Carr, A. (2013) *How square register's UI guilts you into leaving tips*. Available online at: https://www.fastcompany.com/, 2013 (accessed on 25 August 2023).

Chen, Z. et al. (2020) *Cortex Blockchain Whitepaper*. Available online at https://www.cortexlabs.ai/cortexblockchain.

Choi, D. and Lee, K. (2018) 'An artificial intelligence approach to financial fraud detection under IoT environment: a survey and implementation', *Security and Communication Networks*, pp.1–15. Doi: 10.1155/2018/5483472.

Chy, M. and Buadi, O. (2023) Role of data visualization in finance', *American Journal of Industrial and Business Management*, Vol. 13, pp.841–856. Doi: 10.4236/ajibm.2023.138047.

Dolan, P., Elliott, A., Metcalfe, R. and Vlaev, I. (2012) 'Influencing financial behavior: from changing minds to changing contexts', *Journal of Behavioral Finance*, Vol. 13, No. 2, pp.126–142. Doi: 10.1080/15427560.2012.680995.

Elayan, H., Aloqaily, M., Karray, F. and Guizani, M. (2023) 'Internet of behavior and explainable ai systems for influencing IoT behavior', *IEEE Network*, Vol. 37, No. 1, pp.62–68. Doi: 10.1109/MNET.009.2100500.

Franklin, M., Folke, T. and Ruggeri, K. (2019) 'Optimising nudges and boosts for financial decisions under uncertainty', *Palgrave Commun*, Vol. 5, No. 1, p. 113. Doi: 10.1057/s41599-019-0321-y.

Fraternali, P. et al. (2019) 'Visualizing and gamifying consumption data for resource saving: challenges, lessons learnt and a research agenda for the future', *Energy Informatics*, Vol. 2, No. S1. Doi: 10.1186/s42162-019-0093-z.

Fraternali, P. et al. (2019) 'Visualizing and gamifying consumption data for resource saving: challenges, lessons learnt and a research agenda for the future', *Energy Informatics*, Vol. 2, No. S1, p. 22. Doi: 10.1186/s42162-019-0093-z.

French, D., McKillop, D. and Stewart, E. (2020) 'The effectiveness of smartphone apps in improving financial capability', *The European Journal of Finance*, Vol. 26, No. 4–5, pp.302–318. Doi: 10.1080/1351847X.2019.1639526.

French, D., McKillop, D. and Stewart, E. (2021) 'Personal finance apps and low income households', *Strategic Change*, Vol. 30, No. 4, pp.367–375. Doi: 10.1002/jsc.2430.

García, J.M. and Vila, J. (2020) 'Financial literacy is not enough: the role of nudging toward adequate long-term saving behavior', *Journal of Business Research*, Vol. 112, pp.472–477. Doi: 10.1016/j.jbusres.2020.01.061.

Gathergood, J. (2012) 'Self-control, financial literacy and consumer over-indebtedness', *Journal of Economic Psychology*, Vol. 33, No. 3, pp.590–602. Doi: 10.1016/j.joep.2011.11.006.

Harvard Business Review (2023) *Taking the financial services customer experience to the next level*. Available online at: https://hbr.org/ (accessed on 17 July 2023).

Johnson, E.J. and Goldstein, D. (2003) 'Do defaults save lives?', *Science (1979)*, Vol. 302. pp.1338–1339. Doi: 10.1126/science.1091721.

Johnson, E.J. et al. (2012) 'Beyond nudges: tools of a choice architecture', *Marketing Letters*, Vol. 23, No. 2, pp.487–504. Doi: 10.1007/s11002-012-9186-1.

Kahneman, D. (2011) *Thinking, Fast and Slow*, Farrar, Straus and Giroux, New York. Doi: 10.1007/s00362-013-0533-y.

Kim, J., Jhang, J., (Sam) Kim, S. and Chen, S-C. (2021) 'Effects of concealing vs. displaying prices on consumer perceptions of hospitality products', *International Journal of Hospitality Management*. Doi: 10.1016/j.ijhm.2020.102708.

Knihován, L. (2020) 'Digital customer experience in financial services', *IFRS: Global Rules and Local Use – Beyond the Numbers*.

Kothakota, M.G. and Kiss, D. (2020) 'Elizabeth', *Journal of Financial Counseling and Planning*, Vol. 31, No. 2. Doi: 10.1891/JFCP-18-00070.

Kwok, A.O.J. (2023) 'The next frontier of the Internet of Behaviors: data-driven nudging in smart tourism', *Journal of Tourism Futures*. Doi: 10.1108/JTF-11-2022-0288.

Lai, C-F., Chen, S-Y., Wei, Y-F., Chen, M-Y. and Lai, S-Y. (2023) 'IoB-enhanced deep learning for non-specific thermal respiratory rate monitoring', *Proceedings of the IEEE International Conference on Networking, Sensing and Control (ICNSC)*, IEEE, pp.1–6. Doi: 10.1109/ICNSC58704.2023.10319043.

M.G. Organisation (2020) *Mydata-white-paper-english-2020.pdf*. Available online at: https://mydata.org/wp-content/uploads/sites/5/2020/08/mydata-white- paper-english-2020.pdf

Majuri, J., Koivisto, J. and Hamari, J. (2018) 'Gamification of education and learning: a review of empirical literature', *Proceedings of the 2nd International GamiFIN Conference*, Pori, Finland, pp.11–19.

Meng, J. and Junfeng, L. (2019) 'Research on internet financial personalized services based on big data analysis', *Proceedings of the International Conference on Financial Management, Education and Social Science (FMESS'19)*. Doi: 10.23977/fmess.2019.069.

Mertens, S., Herberz, M., Hahnel, U.J.J. and Brosch, T. (2022) 'The effectiveness of nudging: a meta-analysis of choice architecture interventions across behavioral domains', *Proceedings of the National Academy of Sciences*, Vol. 119, No. 1. Doi: 10.1073/pnas.2107346118.

Mezair, T. et al. (2023) 'Towards an advanced deep learning for the internet of behaviors: application to connected vehicles', *ACM Trans Sens Netw*, Vol. 19, No. 2, pp.1–18.

Moghaddam, M.T., Muccini, H., Dugdale, J. and Kjagaard, M.B. (2022) 'Designing internet of behaviors systems', *Proceedings of the IEEE 19th International Conference on Software Architecture (ICSA)*, IEEE, pp.124–134. Doi: 10.1109/ICSA53651.2022.00020.

Moustati, I., Gherabi, N., El Massari, H. and Saadi, M. (2023) 'From the internet of things (IoT) to the internet of behaviors (IoB) for data analysis', *Proceedings of the 7th IEEE Congress on Information Science and Technology (CiSt)*, IEEE, pp.634–639. Doi: 10.1109/CiSt56084.2023.10409989.

OECD (2021) *Artificial Intelligence, Machine Learning and Big Data in Finance: Opportunities, Challenges, and Implications for Policy Makers*, OECD. Available online at: https://www.oecd.org/ (accessed on 28 August 2023).

Oliveira, W. et al. (2023) 'Tailored gamification in education: a literature review and future agenda', *Journal of Education and Information Technologies*, Vol. 28, No. 1, pp.373–406. Doi: 10.1007/s10639-022-11122-4.

Ramanujam, V. and Napoleon, D. (2021) 'Role of big data analytics in the financial service sector', *Big Data Applications in Industry 4.0*, Auerbach Publications, Boca Raton, pp.169–193. Doi: 10.1201/9781003175889-9.

Rosa, P.M. (2022) 'Nudging is the architecture of choice in the world of banking', *Revista de Administração Contemporânea*, Vol. 26, No. 5. Doi: 10.1590/1982-7849rac2022220073.en.

Saleem, M. (2017) 'E-commerce personalization using big data and challenges', *International Journal of Advance Research in Science and Engineering*, pp.595–602.

Shi, E., Chan, T-H.H., Rieffel, E.G., Chow, R. and Song, D.X. (2011) 'Privacy-preserving aggregation of time-series data', *Network and Distributed System Security Symposium*, pp.1–17.

Smith, R., Loibl, C., Imam, K. and Jones, L. (2020) 'Improving financial behaviors through nudges', *The Journal of Extension*, Vol. 58, No. 1. Doi: 10.34068/joe.58.01.02.

Sun, J., Gan, W., Chao, H-C., Yu, P.S. and Ding, W. (2022) 'Internet of behaviors: a survey', *Proceedings of the 5th International Conference on Information Systems and Computer Networks*, IEEE, India. Doi: 10.1109/ISCON52037.2021.9702450.

Team, D. (2018) *dtp-overview.pdf*. Available online at: https://datatransferproject.dev/dtp- overview.pdf

Team, S. (2021) *Home·solid*, Available online at: https://solidproject.org/

Thaler, R.H. (1999) 'Mental accounting matters', *Journal of Behavioral Decision Making*, Vol. 12, No. 3, pp.136–206.

Thaler, R.H. and Sunstein, C.R. (2008) *Nudge: Improving Decisions about Health, Wealth, and Happiness*, Yale University Press, APA PsycNet.

Tong, C., Wong, S.K-S. and Lui, K.P-H. (2012) 'The influences of service personalization, customer satisfaction and switching costs on e-loyalty', *International Journal of Economics and Finance*, Vol. 4, No. 3. Doi: 10.5539/ijef.v4n3p105.

Verhoef, P.C., Kannan, P.K. and Inman, J.J. (2015) 'From multi-channel retailing to omni-channel retailing', *Journal of Retailing*, Vol. 91, No. 2, pp.174–181. Doi: 10.1016/j.jretai.2015.02.005.

Zhang, G. et al. (2021) 'Using an internet of behaviours to study how air pollution can affect people's activities of daily living: a case study of Beijing, China', *Sensors*, Vol. 21, No. 16. Doi: 10.3390/s21165569.

Zhang, P. and Zhou, M. (2020) 'Security and trust in blockchains: architecture, key technologies, and open issues', *IEEE Transactions on Computational Social Systems*, Vol. 7, No. 3, pp.790–801.

Zhao, Q., Li, G., Cai, J., Zhou, M.C. and Feng, L. (2023) 'A tutorial on internet of behaviors: concept, architecture, technology, applications, and challenges', *IEEE Communications Surveys and Tutorials*. Doi: 10.1109/COMST.2023.3246993.