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Digital Payments: A Framework for Inclusive Design

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Abstract

We explore how digital payments, which dominate the payment landscape in Canada, can be made more cognitively accessible. In particular, we are focused on removing cognitive barriers present in many digital interfaces and products. We propose an inclusive approach since involving people with cognitive disabilities in design, testing, and refinement is crucial.

The proposed framework centers on system learnability and user workload as the two key measures of cognitive accessibility in digital payment and banking interfaces. System learnability is determined by measuring first use learnability, steepness of the learning curve and efficiency of the ultimate plateau. Workload is determined by the sub-measures mental demand, temporal demand, frustration and performance.

The framework is broadly applicable to digital and electronic payment methods. We develop and test a prototype interface for voice payments, which successfully demonstrates that the framework provides an effective iterative design approach to enhance cognitive accessibility and usability.

The Bank of Canada can use this framework to create guidelines for more cognitively accessible electronic payment products, including a potential Digital Canadian Dollar. While the framework facilitates efficient evaluation, further validation is still needed. This framework should also be used with broader holistic usability and accessibility testing, recognizing that cognitive accessibility is just one aspect of the user experience.

Topics: Accessibility, Bank notes, Central bank research, Digital currencies and fintech, Digitalization, Financial services

JEL codes: A14, C90, D83, O33, Y80

Résumé

Nous examinons comment l'accessibilité des paiements numériques, le mode de paiement prépondérant au Canada, peut être améliorée au plan cognitif. Nous nous intéressons tout particulièrement aux moyens de surmonter les entraves cognitives présentes dans bon nombre d'interfaces et de produits numériques. L'approche que nous proposons se veut inclusive dans la mesure où la participation de personnes en situation de handicap cognitif aux phases de conception, d'essai et de rodage est indispensable.

Le cadre proposé est centré sur la simplicité d'apprentissage et la charge de travail, deux baromètres essentiels de l'accessibilité cognitive pour les interfaces bancaires et de paiement numérique. La simplicité d'apprentissage mesure le degré de maîtrise qu'acquiert un utilisateur au premier contact d'une application, la raideur de la courbe d'apprentissage, ainsi que l'efficacité d'un système. La charge de travail est la résultante des pressions cognitives et temporelles éprouvées, de la frustration vécue et de la performance de l'utilisateur.

Le cadre s'applique globalement aux méthodes de paiement numériques et électroniques. Nous mettons sur pied un prototype d'interface vocale pour les opérations de paiement. Sa mise à l'essai montre avec succès que notre cadre offre une approche itérative efficace pour améliorer l'accessibilité cognitive et l'utilisabilité.

Ce cadre peut aider la Banque du Canada à créer des lignes directrices pour des produits de paiement électroniques, comme un éventuel « dollar canadien numérique », plus accessibles sur le plan cognitif. Le cadre facilite une évaluation efficace, mais n'élimine pas la nécessité d'une validation complémentaire. Il devrait également s'insérer dans un ensemble de tests holistiques visant à mesurer l'utilisabilité et l'accessibilité, car l'accessibilité cognitive n'est qu'une dimension de l'expérience de l'utilisateur.

Sujets : Accessibilité, Billets de banque, Recherches menées par les banques centrales, Monnaies numériques et technologies financières, Numérisation, Services financiers

Codes JEL : A14, C90, D83, O33, Y80

Introduction

The Bank of Canada has a tradition of making payments accessible, primarily by supplying bank notes to Canadians. Indeed, bank notes remain the simplest payment instrument available because they can be used without access to a network connection or a bank account. And universal accessibility continues to be a priority for the Bank. It has undertaken research into many retail payment activities and methods, including a Central Bank Digital Currency (CBDC)—a hypothetical Digital Canadian Dollar—a public digital payment method that could complement bank notes (Miedema et al. 2020). Accordingly, this research seeks to extend the tradition of accessibility beyond cash, that is, to understand accessibility requirements for electronic and digital payment methods. Generally, any payment not made with cash or cheque is considered an electronic payment, including paying by debit and credit cards. Digital payments are a subset of electronic payments that do not require a physical card, such as a payment from an app, an Interac e-Transfer® and a potential CBDC (Office of the Privacy Commissioner of Canada 2016).

Research into universal access of digital payments reveals barriers in three main areas: digital inclusion, financial inclusion and accessibility for those with disabilities or functional limitations (Sutton-Lalani et al. 2023). Whereas accessibility features for bank notes are limited to the physical format of the note and cannot be customized for the individual, electronic payment methods can leverage a wide variety of accessibility technologies. However, this range of options can also introduce more complexity in the payment experience.

While accessibility is increasingly a domestic and international priority, less consideration is being given to cognitive accessibility. This gap is further amplified as an increasing percentage of Canadians experience the cognitive decline associated with aging. Because making payments is such an important factor for maintaining personal autonomy, cognitive accessibility is an especially relevant area of research into electronic and digital payments. To investigate cognitive accessibility for such payments, we propose a framework focused on system learnability and cognitive workload. By applying the framework systematically to tasks within the payment experience, we arrive at a set of key design adaptations to improve the cognitive accessibility of electronic payments.

Research context

An emerging domestic and international priority

Recently, governments and institutions have put considerable effort into incorporating accessibility broadly in international priorities and domestic laws. For example, the United Nations Disability and Inclusion Strategy lays out a framework for implementing the Convention on the Rights of Persons with Disabilities (CRPD). Canada is one of 183 countries who have ratified the CRPD, committing to "ensuring that there are national laws to prevent discrimination, eliminating barriers to accessibility, and working to promote the capabilities and contributions of people with disabilities" (Library of Parliament 2021, ii). To fulfill these obligations, Canada passed the *Accessible Canada Act* in 2019, aimed at making Canada barrier free by 2040 (Employment and Social Development Canada 2023). To meet the mandate of the Act, Accessibility Standards Canada is creating accessibility standards for all federally regulated entities, including banks and Canadian crown corporations (Employment and Social Development Canada 2019). Given this policy context, accessibility in general is a high priority for the design and delivery of retail digital and electronic payment methods, including a potential CBDC. However, cognitive accessibility is of particular interest for these payment methods for many reasons.

Cognitive accessibility and disability

Cognitively accessible systems benefit people with cognitive disabilities, those with functional limitations and those who desire a simpler user experience. While quantifying the latter groups is difficult, some research is available on the prevalence of cognitive disabilities. Cognitive disability is defined as "a situation of disadvantage experienced by individuals with cognitive abilities that differ from what is considered typical, in one or more of the following domains: (1) attention, (2) executive functions, (3) learning and memory, (4) language, (5) perceptual motor skills or (6) social cognitions." (Cobigo et al. 2024, 21–22). It is also important to note that "people with cognitive disability constitute a heterogeneous group with a range of co-existing cognitive strengths and limitations that often evolve over time and can be persistent, episodic or temporary" (Cobigo et al. 2024, 22).

Determining the prevalence of cognitive disability often relies on medical diagnosis and self-disclosure. Statistics Canada's Canadian Survey on Disability points to the approximate number of Canadians experiencing cognitive disabilities. In 2022, 1.95 million Canadians (or approximately 5% of the population) aged 15 and older reported memory-related disabilities, 2.3 million (6%) reported learning disabilities and 3.9 million (10%) reported mental health-related disabilities (Statistics Canada 2023). These numbers cannot be considered additive, as users may experience more than one disability at a time, though they do give an idea of how common these disabilities are. Each of these categories increased relative to the previous survey data from 2017. While many factors contribute to an increase in reported disabilities, the aging population in Canada is a significant one. Adults over 64 are almost twice as likely to have a disability as those of working age (15 to 64 years). And as the Canadian population continues to age, we can expect the prevalence of disabilities to rise and the need for payment methods that support cognitive disabilities to increase (Sutton-Lalani et al. 2023).

While cognitive disability describes the experience of the individual, cognitive accessibility speaks to the features in the environment or infrastructure that facilitate an individual's participation and autonomy.

Cognitive accessibility includes adaptations and accommodations to alleviate difficulties people with cognitive disabilities face. Examples of such measures are:

- simplifying the environment
- slowing down processes
- offering information in a language that is easy to understand
- using assistive technology, communication aids and information technology to support users' optimal functioning

Despite the broad implications, cognitive accessibility is relatively understudied and underserviced in the payments market. This lack of attention, the strong prevalence of cognitive disability and the history of accessible bank notes make cognitive accessibility an important area of focus for CBDC research and the future of payments.

Complexity and poor design as barriers

As with any new technology, electronic and digital payment methods present inherent trade-offs in their design that warrant close attention. On one hand, digital technology itself offers opportunities to increase accessibility through new features and innovative design. On the other hand, these same payment technologies can add many layers of complexity to the transaction process, introducing new barriers that did not apply to the world of cash. A more complex payment process increases the cognitive load necessary for a user to perform fundamental tasks, making that process more difficult for all users and impossible for some. Complexity and design challenges are also observed in the language used to interact with users and in the lack of options for users when they experience challenges. Live agent support and training is rarely available to address the challenges that arise with electronic and digital payments. While voice recognition software aims to replicate the experience of human support, inaccuracies increase users' frustrations, especially when the users have a speech impairment or do not have English or French as their first language.

The concept of simplicity is important to avoid introducing cognitive accessibility barriers for electronic and digital payments. Simple refers to something that is "easily understood or done; presenting no difficulty" (Canadian Oxford Dictionary 2004). Simplicity is especially critical in digital payments, where small user errors could lead to financial losses. While the requirement for simplicity in payments may be more obvious for those experiencing cognitive disability, the advantages of simplicity apply to all users. For example, 43% of Canadians surveyed responded that they valued the ease of using bank notes (Bank of Canada 2023), suggesting that simplicity is desirable for a broad set of users. For those who do not currently experience barriers related to cognitive accessibility, a simpler system could offer a value-add service, decreasing the mental load required in a digital world designed to compete for users' attention.

Workarounds and risks

Preventing or addressing accessibility barriers in the payments landscape requires a strong understanding of how users experience cognitive accessibility today. When it comes to financial services, gaps around cognitive accessibility result in not just frustration or inconvenience, but also material risks for users and their supporters. While cognitive accessibility challenges are not limited to the aging population, this demographic group provides a useful example of some of the risks and barriers that exist. This is especially true because, as older adults face late-life disabilities, they often retain responsibilities for banking and paying bills (Xiang et al. 2021). At the same time, sensory changes related to aging and cognitive decline often affect a persons' use of technology (Dixon, Anderson and Lazar 2022), making it even more difficult to perform tasks related to electronic and digital payments.

When users encounter barriers, they often create workarounds to accomplish the tasks, or they simply abandon the technology. Workarounds can lead to technologies being used differently than intended, resulting in the introduction of risks to the user. In the case of cognitive accessibility, workarounds most often include seeking support from a caregiver or trusted other. Specific to online banking, research shows that older adults share credentials with close others at a high rate (Latulipe, Dsouza and Cumbers 2022). More precisely, a survey conducted by the Financial Consumer Agency of Canada finds that 61% of older adults would give their bank permission to contact someone trusted (Financial Consumer Agency of Canada 2019). While secondary support can provide meaningful improvements for those facing cognitive barriers, sharing credentials might also risk privacy and security and lead to financial exploitation (Latulipe, Dsouza and Cumbers 2022). Further, such sharing often violates the terms and conditions of financial institutions, meaning that a user loses protection from unauthorized payments or fraud (Financial Consumer Agency of Canada 2024). This is especially relevant for people with intellectual disabilities, who face increased vulnerabilities around sharing personal data, including bank account information

(Chalghoumi et al. 2019; Lussier-Desrochers et al. 2017). In addition, research shows that elderly adults with even mild cognitive impairments are particularly vulnerable in terms of financial capabilities because cognitive impairment can reduce their ability to recognize scams such as email phishing, follow recommended password guidelines and consider the implications of sharing personal information (Mentis, Madjaroff and Massey 2019). The risk is further amplified by the emergence of technology such as generative AI, which could facilitate financial crimes such as payment scams.

Existing standards and best practices

In recent years, significant research and the development of guidelines and standards for accessible and usable digital products have occurred. While typically distinct, usability and accessibility features have considerable overlap when it comes to cognitive accessibility, and many recommendations are based on basic usability principles (Mariger 2024). While not specific to electronic and digital payments, these guidelines are an optional resource for designers or creators looking to make their products more accessible. Notable examples include the seven principles for universal design, developed by the Centre for Excellence in Universal Design (Centre for Excellence in Universal Design 2024) and the 10 Usability Heuristics from Nielsen Norman Group (Nielsen 1994). Both sets of guidelines are developed to address accessibility broadly and emphasize the need for simplicity and ease of use as a core principle. Another set of overlapping principles is the prevention and tolerance of error, especially important factors when we consider cognitive accessibility for payment systems or a product like a possible CBDC, where trust that the system has performed functions as intended is paramount. ISO Standard 21801-1:2020(E) also provides general guidelines on cognitive accessibility, including recommendations for mitigations, although further interpretation is required to apply this standard to electronic and digital payments.

Within Canada, the federal government has published specific guidelines for cognitive accessibility as part of the renewed focus on designing accessible services. These guidelines relate to web content but also offer widely applicable principles such as “keep content short, clear and simple” and “use multi-modal materials like audio and video” (Government of Canada 2024). Internationally, the W3C Web accessibility initiative has published similar recommendations, such as making content adaptable and distinguishable, providing users with enough time and making interfaces easy to navigate (W3C Web Accessibility Initiative 2022). W3C also publishes the Web Content Accessibility Guidelines (WCAG), their official set of standards, which includes a set of success criteria related to improvements for cognitive-, learning-, mobility- or vision-related barriers (W3C 2023).

Notably, the W3C guidelines include a caveat for cognitive accessibility. The WCAG 2.2 indicates that “significant challenges were encountered in defining additional criteria to address cognitive, language and learning disabilities, including a short timeline for development as well as challenges in reaching consensus on testability, implementability and international considerations of proposals” (W3C 2023, Introduction). This experience illustrates a broader theme related to cognitive accessibility. In both research and product development, cognitive accessibility needs are less well represented than those of other disabilities. For example, visual disabilities are the focus of significantly more research than cognitive disabilities, despite their similar prevalence. Research suggests that this is largely because disabilities such as vision impairment are more tangible for researchers and often better funded (Sutton-Lalani et al. 2023).

A framework for cognitively accessible digital payments

Guidelines such as those described above do not exist specifically for digital payments. Also, the result of some adaptations may vary greatly depending on the type of product or service in question. For example, plain language for health services may differ from plain language for financial services. Therefore, our framework assesses how effective general guidelines for cognitive accessibility could be when applied to electronic and digital payments and a hypothetical CBDC. By developing a structured and consistent approach to user testing these guidelines, we identify a set of refined and validated adaptations to make digital payments cognitively accessible. These adaptations will be combined into guidelines for digital payments and a possible CBDC design. **Figure 1** illustrates the five-phase process used to develop our domain-specific guidelines from more general principles. **Figure 2** further describes Phase 4 in detail, which depends on the framework proposed in this paper.

Figure 1: Overall process for refining guidelines

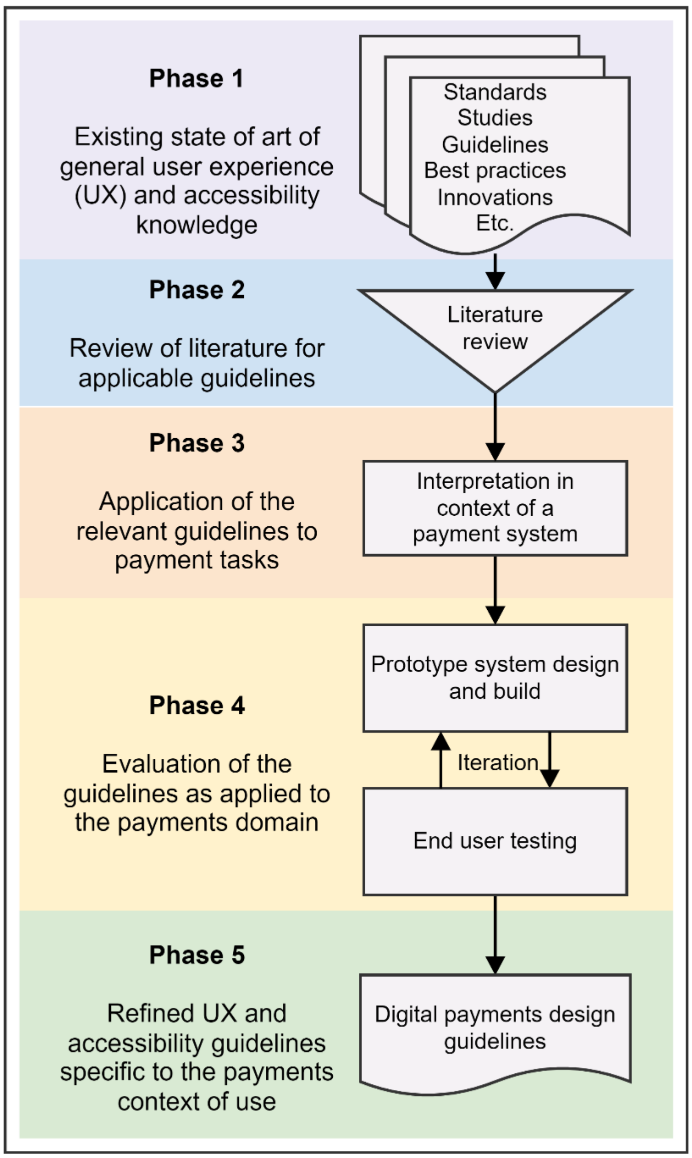
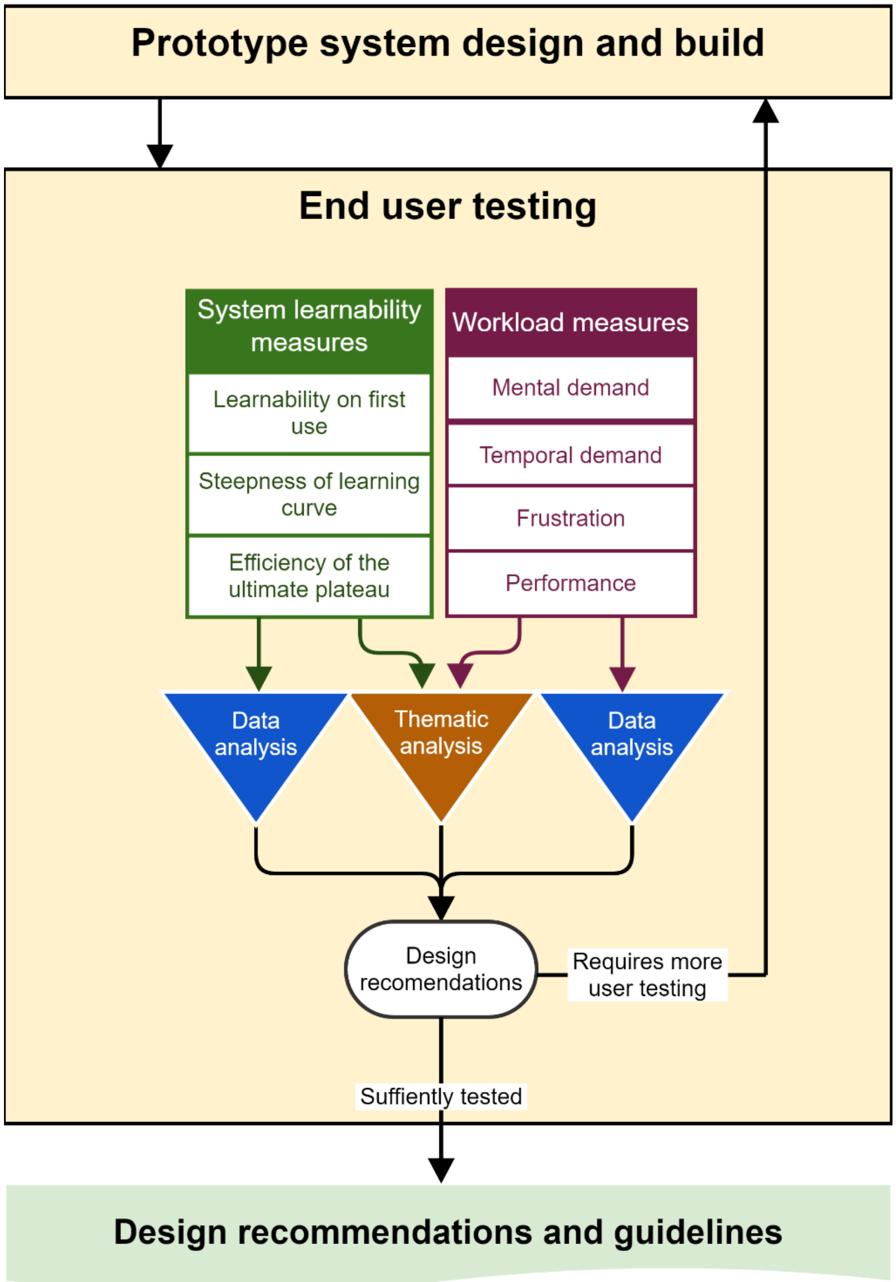


Figure 2: Detailed diagram of Phase 4 of the refinement process
Application of system learnability and workload measures



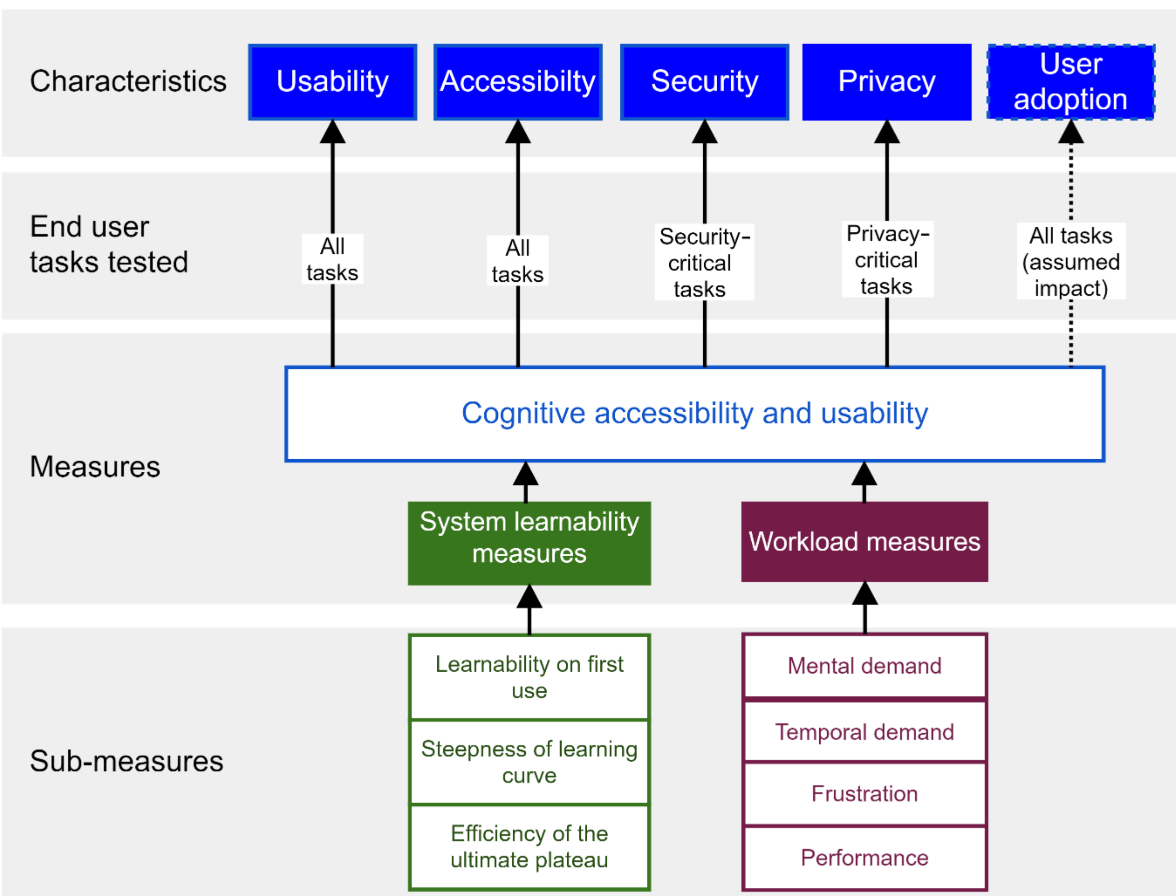
Components of the framework

User considerations for electronic and digital payments can largely be divided into five main characteristics: usability, accessibility, security, privacy and user adoption. These factors are highly interconnected, and all are equally relevant. In our framework depicted in **Figure 3**, we directly measure cognitive useability and accessibility for key user tasks. Focusing on quantifying these characteristics allows us to develop a set of measures to evaluate designs.

Accessibility improvements should be designed to not compromise privacy and security measures (International Standards Organization 2020). We consider security and privacy through evaluating the usability and accessibility of security- and privacy-critical tasks for payment systems, such as user onboarding and authenticating users. The goal is to reduce the impact of these tasks on users and, accordingly, the users' possible desire to circumvent security measures they find difficult to use.[1]

While usability, accessibility, security and privacy may be obvious characteristics to consider, the motivations behind including user adoption warrant some explanation. Widescale user adoption is likely a necessary precondition to merchant acceptance, meaning merchants will not start accepting a payment method until a large portion of their customers have (Henry et al. 2023). As a result, a method of payment cannot be considered useable by all consumers until it is widely adopted by merchants. User adoption, however, is not directly measured; rather, it is implied that a more usable and accessible product will remove barriers and thus increase adoption.

Figure 3: Framework components



[1]Onboarding is the process of setting a user up to use a product. The process differs depending on the product but often includes the user receiving the product and creating an account.

Measures of system characteristics

Borrowing from the Nielsen Norman Group's usability heuristics (Nielsen 1994), we identify system learnability and workload as areas of particular relevance for those with cognitive accessibility needs. Regarding system learnability, the ongoing shift toward electronic and digital payments implies an existing learning curve for users who may traditionally rely on cash for their payment needs. A decline in cash use or a continued migration of goods and services to the digital economy may mean that some users are forced to transition to digital payments for the first time, as opposed to gradually adopting them. These users may not be familiar with the common design patterns of digital systems. In addition, the lack of consistency in user interface design and workflows between products worsens the challenges, even for seasoned users of similar technology or products. This means a large learning gap exists for new users to make digital payments, increasing the complexity of both onboarding and becoming comfortable with digital payments and a potential CBDC.

Workload is a common measure for usability and in most cases decreasing workload increases usability. The Bank for International Settlements identifies a similar concept, mental burden, as a key factor related to complexity and thereby accessibility of a potential CBDC (Bank for International Settlements 2023). We include workload as a measure in our framework, given its applicability to electronic and digital payments as well as to a hypothetical Digital Canadian Dollar.[2] Typically, and for digital payment systems generally, low cognitive workload is preferred for parts of the system intended for frequent and goal-oriented use.

Sub-measures

We assess learnability and workload through a set of sub-measures based on well-defined standards. We define system learnability using ISO 25010 for system and software engineering. This standard considers how well specific users can achieve specific goals in a specific context, using a product or system effectively, efficiently, free from risk and with satisfaction (International Organization for Standardization and International Electrotechnical Commission 2011). Consequently, in our framework we evaluate the system learnability against three main sub-measures described in **Table 1**: learnability on first use, steepness of the learning curve and efficiency of the ultimate plateau (i.e., the height of productivity that users can reach with this interface once they have fully learned how to use it). We use these sub-measures to determine the overall measures, and they serve to guide system improvements that target specific sub-measures dragging down an overall measure.

[2] A CBDC may incorporate offline payments while remaining a digital payment method. More information on an offline CBDC can be found in Minwalla et al. 2023.

Table 1: System learnability sub-measures

System learnability sub-measure	Description	Unit of measure
Learnability on first use	Learnability on first refers to how much support a user needs to learn the system, or if they can learn to use it quickly and independently. This is relevant for people who may not have access to support networks, such as family or friends, who can teach them the system. For the system provider, the easier the system is to learn, the lower the cost of support is. We calculate the percentage of tasks completed successfully on first use of the system, with a high percentage indicating that the system is intuitive and easy to use independently and a low percentage indicating the system is challenging to learn and that users may require support.	Percentage
Steepness of the learning curve	A steep learning curve is desired and indicates that the user can quickly learn the system, whereas a shallow learning curve indicates the system takes longer to learn. This sub-measure is expected to impact user retention, as users could become discouraged with a system that takes too long to learn. We calculate the steepness of the learning curve by plotting the percentage of tasks completed during each subsequent use of the system and observing the increasing performance until a plateau is reached. This rate of change is then subjectively deemed high (or steep) or low (or shallow).	High/low
Efficiency of the ultimate plateau	Since payment systems are routinely used, the ultimate efficiency of this system should be high so as not to burden the user. We determine this sub-measure subjectively by comparing the plots of percentage of tasks completed and finding the plateau (the point at which users stop improving). Since the user's efficiency may plateau then continue rising, we look for the ultimate plateau, which is ideally at high efficiency. If the plateau occurs when users can complete all or most of the tasks, the efficiency is high; otherwise, it is deemed low.	High/low

Overall system learnability can be roughly determined from the sub-measures by converting "First use learnability" to a binary score. This is done loosely based on the following criteria:

- Complex tasks: If a complex task scores 60% or higher, it is considered high learnability. If it scores below that percentage, it is considered low.
- Simple tasks: If a simple task scores 80% or higher, it is considered high learnability. If it scores below that percentage, it is considered low.

- Flexibility: This criterion is not strict because task complexity varies. Also, it is normal for users to need some time to learn a new system, especially for complex tasks.

We use the following three descriptions to classify overall system learnability:

- High learnability: The system scores high on all three sub-measures of learnability.
- Medium learnability: The system scores low on one of the three sub-measures.
- Low learnability: The system scores low on two or more of the three sub-measures.

To assess cognitive workload, we use the common definition of workload, being "the amount of work to be done by a person" (Canadian Oxford Dictionary 2004). We modify a combination of measures from the NASA Task Load Index (NASA Ames Research Center 1986) and the System Usability Scale (Brooke 1996) to create four sub-measures described in **Table 2** below: mental demand, temporal demand, frustration and performance.

Table 2: Workload sub-measures

Workload sub-measure	Description	Unit of measure
Mental demand	Mental demand is the mental effort required to complete the task. The lower the mental demand on the user, the larger the range of cognitive ability the system could support. Extending this range makes the system more accessible for younger and older users. We evaluate mental demand by asking each participant to rate if it was hard to finish the task. A score of 1 indicates it was not hard, and a score of 3 indicates it was hard.	Scale from 1 to 3
Temporal demand	Users with cognitive disabilities require more time to work with a system; therefore, minimizing temporal demand—or time pressure—is important. This is especially the case when time limits are imposed on a user, such as a voice system awaiting input that will time out after a set period. We evaluate temporal demand by asking each participant to rate the speed of the system, then assign a score from 1 to 3. A score of 1 indicates the system speed was appropriately slow, and 3 was too fast.	Scale from 1 to 3
Frustration*	A frustrated user will become less motivated to continue to use the system and will likely have a lower performance. We measure frustration subjectively by user-reported feelings while performing the task. We then assign a score of 1 (indicating low frustration) to 3 (indicating high frustration).	Scale from 1 to 3
Performance*	Performance refers to the user's ability to complete the sample tasks and whether the user commits errors while doing so. We evaluate performance on a scale of 1 (indicating high performance) to 3 (indicating low performance).	Scale from 1 to 3

* Frustration and performance can be considered compound measurements. They are affected by the other factors and are important indicators for overall system usability.

We calculate the overall workload rating from the sub-measures using a weighted average, based on participant ranking. Each participant compares pairs of sub-measures (presented to them in plain language with further explanation as needed) and decides which one had a bigger impact on them. Examples of paired answers to the question "Which of the two had the most impact on you for this activity" are:

- the complexity of the system (mental demand) OR your confidence (performance) when using the system
- the speed of the system (temporal demand) OR your feelings (frustration) when using the system

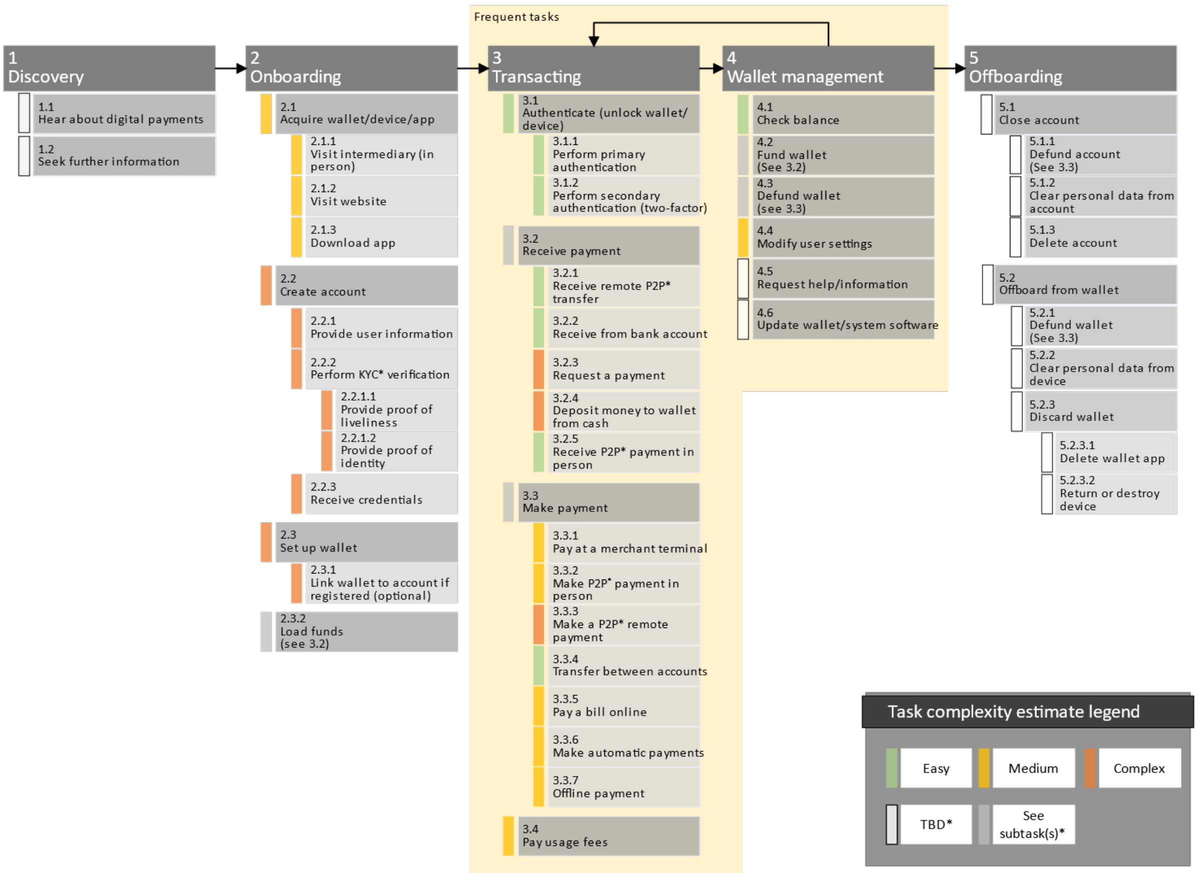
The sub-measure considered more important than its pair gets one point. After comparing all pairs and assigning points, we give each sub-measure a score (weight) between 0 and 3. We then use these weighted averages to calculate an overall workload score for the system.

User tasks under evaluation

To complete the framework, we layer these sub-measures and their evaluation criteria over a set of payment tasks. In a hypothetical scenario in which a CBDC is issued, the expected payment journey of a CBDC user can be broken into a task hierarchy, as depicted in **Figure 4**. We divide high-level tasks into sub-tasks and assign them a complexity estimate of easy, medium or complex based on, but not limited to, length of activity, number of steps, complexity of user inputs and expert opinion. The differences in complexity of three sample tasks is illustrated by the workflow diagrams in **Appendix A**.

We also assume the tasks are either frequent (indicated by the yellow area in Figure 4) or less frequent. Our analysis focuses on frequent tasks; these should be learnable and efficient since they will be performed many times and will greatly impact the user experience. Less-frequent tasks, such as onboarding and account verification, should be designed to not introduce barriers to adoption or use of the system. A high percentage score on first-use learnability is desirable for infrequent or single-time tasks since the user will not have the benefit of repetition to learn them. These tasks will require careful design because they are often complex and subject to increased security and privacy measures.

Figure 4: Task hierarchy diagram



Note: KYC means know your customer, the process of identifying a customer following the standards set by Financial Transactions and Reports Analysis Centre of Canada, or FINTRAC. P2P means peer to peer. In the legend, identifies tasks that have not yet been analyzed for complexity, and therefore their rating is still to be determined. If the complexity of a task is not easily determined by the sub-tasks, we instead refer to the sub-tasks ("See : tasks") and do not assign a complexity to the higher-level task.

Together, a payment method's characteristics, the key measures and an evaluation of user tasks form the basis of our framework. This framework can be used to evaluate potential electronic payment methods for their cognitive accessibility.

Case study—voice payments

To validate the framework for simple electronic and digital payments, we apply the methodology to voice payment technology. We choose voice payments for several reasons. Firstly, voice interfaces are widespread in the current technology landscape (available both via task-specific devices and built into smart phones). Additionally, individuals who are blind or partially sighted already commonly use voice interactions, and users would likely expect them to be available with digital payments. Lastly, we want to determine how successful this technology, aimed at addressing barriers related to vision, would be at making digital payments cognitively accessible.

Prototype testing for voice payments

We built a prototype voice interface system and tested it with 29 participants with cognitive disabilities, using an iterative method adapted for cognitive accessibility. To facilitate testing, we wrote a procedure based on the framework and collected data on user experience, including task completion and adapted learnability and workload scales for key user tasks of the prototype.

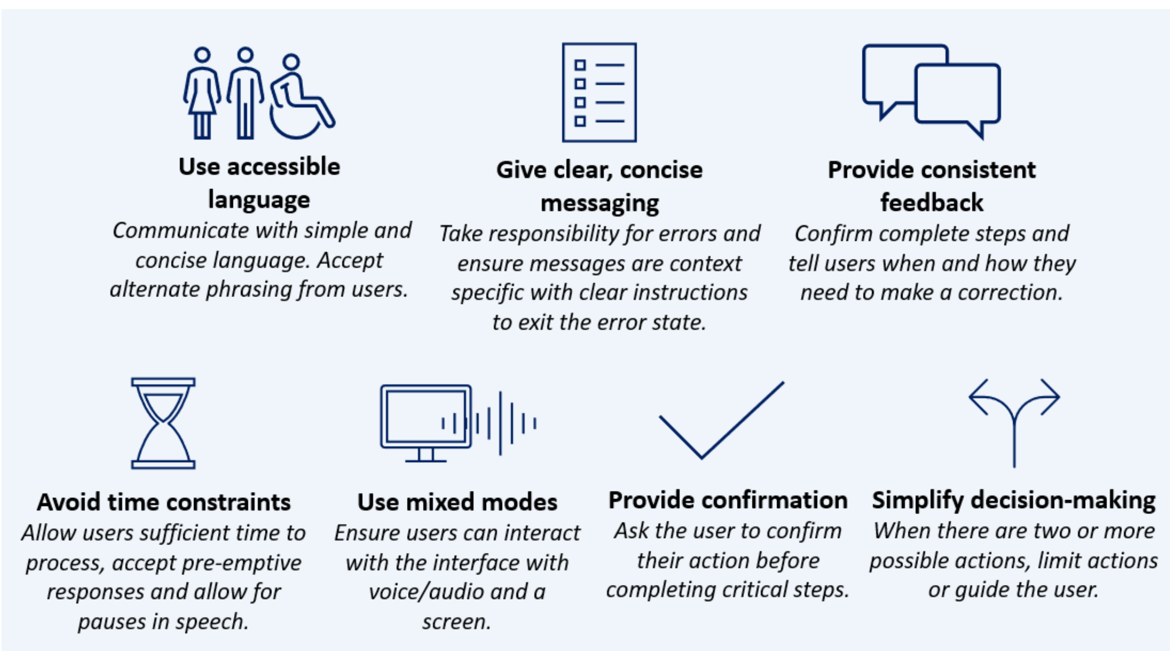
The participants have a range of lived experiences and include persons living with dementia or traumatic brain injury, persons who identify as having an intellectual disability and persons who identify as being neurodivergent. In addition, the participants have diverse support needs, ranging from caregiver support to independent living.

An initial round of remote prototype testing was completed, with rapid implementation of feedback to improve the prototype prior to the second round of remote testing. The participants performed key sub-tasks from the payment task hierarchy, and we assessed the system performance using the sub-measures related to system learnability and cognitive workload. Following the testing, we conducted remote, semi-structured interviews with the participants to gather detailed qualitative information on the usability of the prototype and cognitive accessibility challenges they experienced.

Design adaptations for cognitive accessibility

We based the initial prototype on seven adaptations (see **Figure 5**), derived from a preliminary literature review of best practices for cognitively accessible design in general. We interpreted and adapted these general findings to the payments context and then tested the design adaptations in the first round with the participants.

Figure 5: Design adaptations for cognitive accessibility



Following the first round, participant feedback motivated us to iterate and adapt the prototype design. We applied these refinements to three of the seven cognitive accessibility adaptations:

Use mixed modes	***Improve the quality of visual cues by adding colour to aid in navigation.***
Use accessible language	***Include recognition of "I don't know" as a response and add more recognized commands.***
Avoid time constraints	***Increase time allotted for user response.***

Additionally, we removed the password necessary to log in to the system because it caused confusion. The password was not part of the workflow intended to be tested; it was simply an artifact of the prototype. While it does not fall into the adaptations above, this step illustrates a key trade-off between accessibility and security. Many commonly used security or authentication techniques introduce frictions for users with cognitive accessibility needs. Nevertheless, security remains an important priority for all users of electronic and digital payments, and the relationship between accessibility and security warrants further investigation.

User testing results

To determine system learnability sub-measures, we used the success rate of completion as well as monitor the variance across tasks and testing rounds (**Table 3**). For instance, the first round of simple transactions had 36.9% task completion, which indicates that users experienced significant challenges due to poor system learnability.

Table 3: Percentage of tasks completed successfully by users with cognitive disabilities

Transaction	Round 1	Round 2
Simple	**36.9 %**	**95.7 %**
Medium	81.3 %	83.3 %
Complex	71.4 %	68.2 %

We used a logarithmic scale to plot the percentage of participants who were successful in completing each task (**Chart 1**) to calculate the steepness of the learning curve and efficiency of the ultimate plateau. The curve steepness and the plot are characterized by how quickly the participants learned to use the interface before they reached a plateau. The plot indicated a quick jump between the first and second uses of the system (between task 1 and task 2). This jump in the plot comes from the 44% increase in task completion between their first (simple) task and second (medium) task during round 1 of testing. Despite the second task being more complex, this plot indicates a steep (efficient) learning curve. Between the second use of the system and the third use (task 3), the percentage of successful participants decreased by 9.8%, which was deemed not statistically significant through a t-test. The plot also shows a plateau between the second and third uses, indicating ultimate efficiency of this system. The rest of the task completion scores were high and remained nearly the same between rounds. A t-test shows the minute differences in those scores are not statistically significant.

Chart 1: Percentage of tasks successfully completed

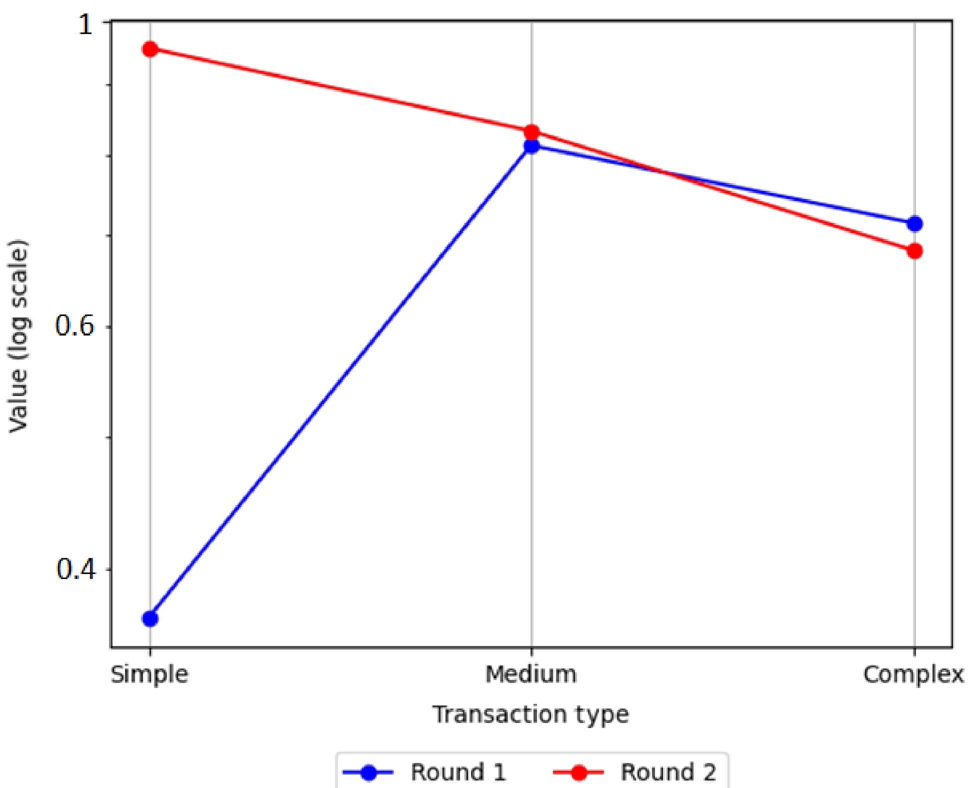
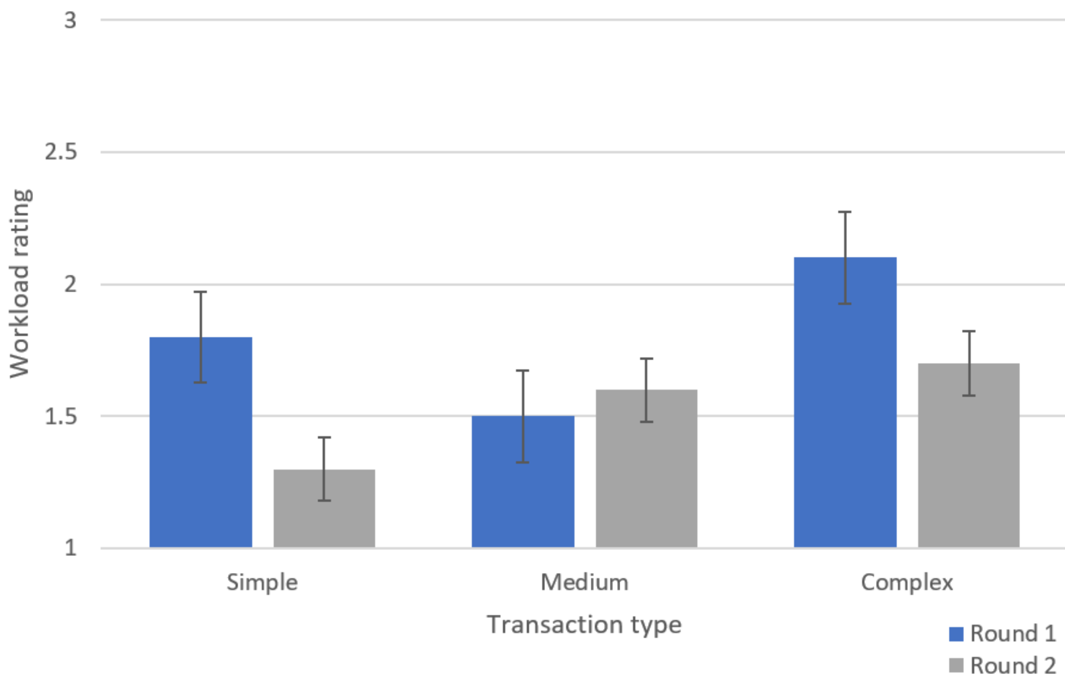


Chart 2 depicts the results from testing all four sub-measures of cognitive workload, both before and after the adaptations. The average workload scores out of 3 for the simple, medium and complex transactions are, respectively, 1.84, 1.55 and 2.11 for the first round and 1.32, 1.56 and 1.70 for the second round. Note that the relatively higher workload for the simple task in round 1 when compared with the medium task in that same round is likely partially due to the simple task being the first interaction the participants have with the system. Therefore, the workload of the simple task is confounded with the added cognitive burden of learning to interact with a completely new system, while the other two tasks would be affected much less.

Following our refinements to three of the adaptations, the overall workload score went down considerably in round 2 for both simple and complex tasks. However, it remained the same for the medium task. Since the medium task already had a low (1.55) first-round workload rating and a final workload rating falling as expected between the simple and complex tasks, we interpret the lack of change as the medium task having already been optimized by the first iteration of adaptations. Overall, after the second round, the system performed well in terms of workload scores, indicating that the adaptations were effective. This is demonstrated by the linear proportional behaviour of the workload rating versus the transaction complexity.

Chart 2: Workload ratings by transaction for rounds 1 and 2



Note: Error bars indicate standard error.

While they do contain some nuances, the findings suggest that a voice payment system built according to the adaptations above is highly usable by persons with cognitive disabilities. Evidence comes from the high system learnability ratings after the second round and the cognitive workload scores falling withing the low end of the scale. The biggest contributor to workload was the effort required to use the system, due to poor voice recognition. This contributed to increased frustration, indicating that the issue was technological and not a lack of design adaptations for the participant. Further, the results imply that this user group is likely to use this technology. However, qualitative feedback reveals that concerns remained about protecting privacy when using a voice payment system, especially in public spaces. If unaddressed, this issue may be a barrier to adoption and broad use. The trade-offs between privacy and security on the one hand and accessibility and convenience on the other are critical for payment system design and require further research. Additionally, the simple task's relatively high workload for the first round illustrates the need for careful design of the first tasks a user will perform with a system because even a simple task will be made more difficult by a user's unfamiliarity with that system.

From adaptations to principles

The success of our adaptations and prototype testing suggests that guidelines based on adaptations for high system learnability and low cognitive workload, developed and validated with persons who face cognitive accessibility barriers, can increase system usability. While the adaptations were successful in improving the voice payments prototype, they also serve as key principles that can be leveraged more generally for cognitively accessible electronic and digital payments. In many ways, these adaptations are much more specific to the payments landscape than those found in current usability standards. Many of the adaptations in Figure 5 could be incorporated into guidelines for designing user experiences for digital payments and used in conjunction with existing standards and user testing to improve universal accessibility.

To inform general principles for electronic and digital payment systems, adaptations should be tested with more users and on other parts of the payment experience. Similarly, interface modalities other than the voice payments interface tested so far should be tested using the same adaptations. This can determine if they are equally effective in other common modalities, such as smartphone-sized visual interfaces like an app, or chat-style text interfaces. We expect, however, that since these adaptations are derived from a variety of source materials, including studies and standards not specific to audio interfaces, they will remain effective in other common modalities. Further, other adaptations to payment systems undoubtedly exist that could and should be added to this set.

Conclusions

We develop our framework to improve the cognitive accessibility of a potential CBDC, but it can be applied more broadly to any digital or electronic payment methods. Ultimately, this framework evaluates the cognitive accessibility of digital payment products, either to determine their suitability for a user population or to form the basis of design recommendations to improve accessibility and usability of those products. At the Bank of Canada, we will use the framework to develop guidelines for more cognitively accessible electronic payment products, including in the context of a hypothetical Digital Canadian Dollar, and for a variety of technologies within the digital payments space. This framework can also inform and help guide key stakeholders and vendors—manufacturers of electronic bank notes, for instance—in designing more accessible products.

This framework is essential due to the prevalence of cognitive accessibility needs in payments and the important role banking and financial transactions play in society. Involving people with cognitive disabilities in the design, testing and refining of design guidelines is particularly important; determining accessibility barriers and related solutions is impossible without their direct involvement.

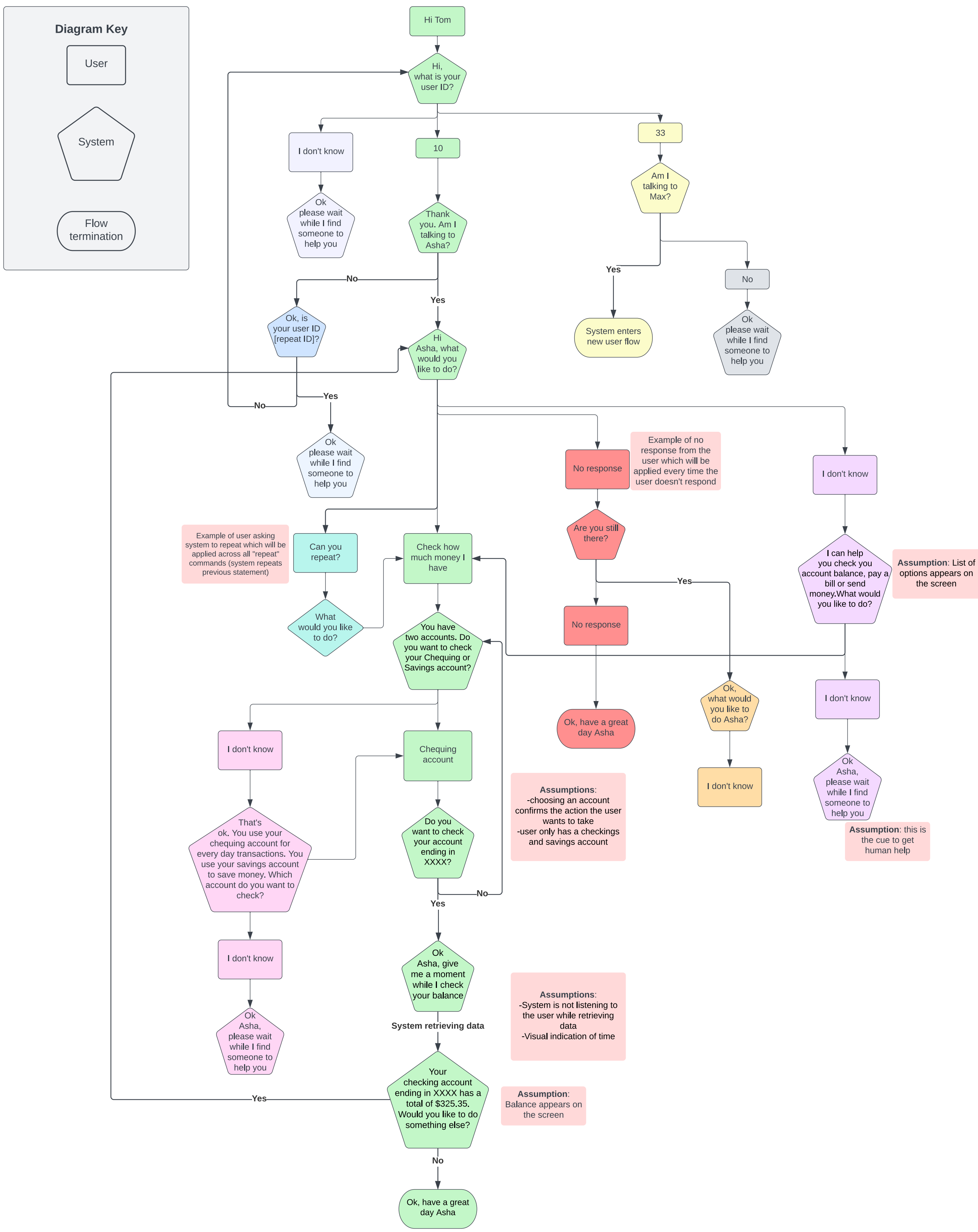
We will continue to develop and use the design framework presented in this paper because it allows for efficient evaluation of system learnability and cognitive workload, as demonstrated in the voice payments case study. The workload measurements match the estimated task complexity, suggesting that the sub-measures are accurate. However, more validation is needed.

This work is based on testing of a voice payment technology for a small sample of a prototype system. While an efficient way to conduct testing in very early stages of the system design, this type of testing does not replace holistic usability and accessibility testing of the entire product or payment method. Additionally, cognitive accessibility, while very important, is only one aspect of accessibility, and accessibility is only one aspect of the user experience. Therefore, this framework is intended to be used as one part of a larger user experience design system.

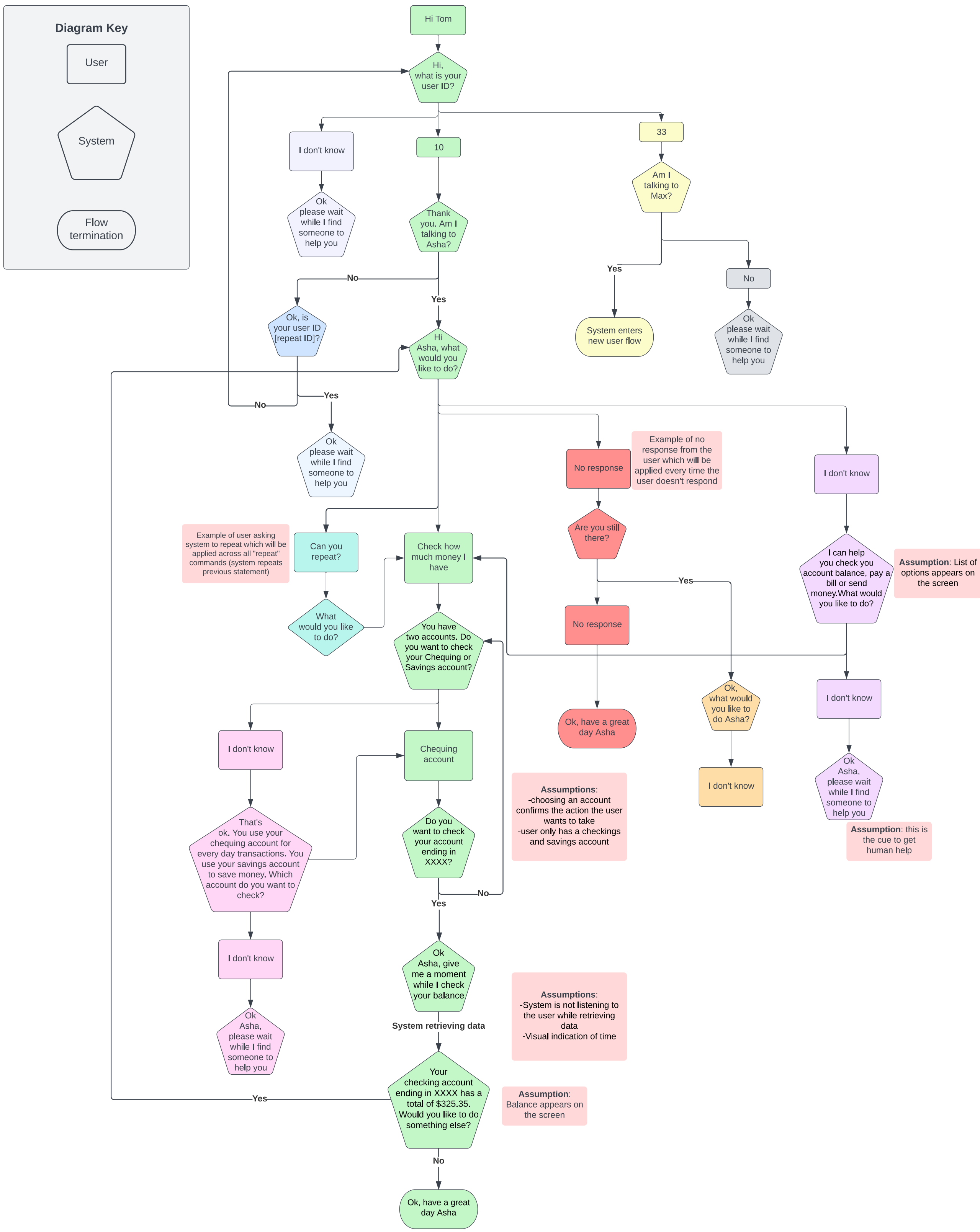
Future work with the framework will be to further develop the measures by examining the infrequent but security- and privacy-critical tasks for onboarding. During the evaluation of the onboarding phase of the workflow, we will determine if additional or different measures are more appropriate or necessary for this type of task. Additionally, we will focus on another user group, elderly adults, to test the procedure with this important but often under consulted group.

Appendix A: System workflow diagrams

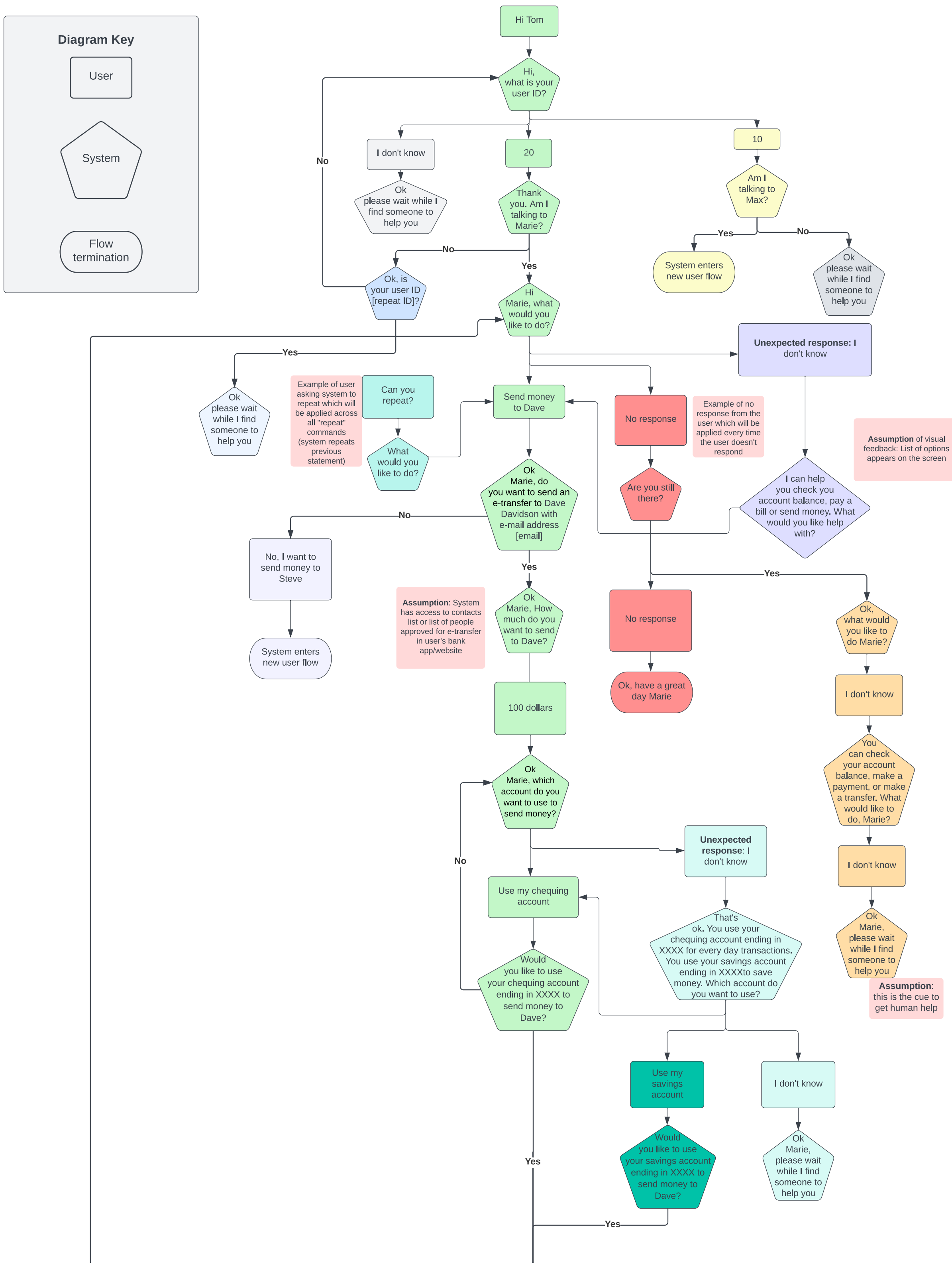
Simple transaction—system workflow



Medium transaction—system workflow



Complex transaction—system workflow



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Complex transaction—system workflow continued

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