Evaluating a visual mobile banking app for users with subjective low numeracy

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Declaration Statement

I hereby certify that the material, which I now submit for assessment on the programme of study leading to the award of Master of Science, is entirely my own work and has not been taken from the work of others except to the extent of such work which has been cited and acknowledged within the text of my own work. No portion of the work contained in this research project has been submitted in support of an application for another degree or qualification to this or any other institute.

_____
Alexander Stewart

05-May-2021

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Date

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Evaluating a visual mobile banking app for users with subjective low numeracy

Exploring a visually interactive financial management system in a mobile banking context to assist users with subjective low numeracy.

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Financial well-being is one of the many aspects of life affected by low numeracy. The required cognitive ability to successfully and confidently conduct everyday economic activities, while using an online banking platform have been, to date, reflective of users who have a medium to high ability in numeracy. Digital banking interactions are developed on the back of numerically symbolic based interactions. However, one of the critical impairments often associated with low numeracy, a magnitude processing deficit, is directly impaired by associating symbolic numbers with their equivalent magnitude. Using a User-Centered Design process, a visual financial management system was created and tested with 40 participants of various reported subjective numeracy scores. The visual system was designed around the visual representation of money instead of traditional systems that have been purely symbolic-based. The study results indicated that the interactive visual system was the preferred design compared to the symbolic system for the lower numeracy group. Furthermore, it also improved financial awareness and consideration.

CCS CONCEPTS • Human-centered computing • Human-computer interaction (HCI) • Interactive systems and tools • User interface toolkits

Additional Keywords and Phrases: Subjective low numeracy, Mobile banking app, Magnitude processing, Non-symbolic number system

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1 INTRODUCTION

The recent innovation and growth within the mobile banking sector has provided the opportunity to inclusively design mobile services, which are accessible and usable by as many people as possible [1]. This project outlines the research activities undertaken to create an alternative non-symbolic based design system for mobile banking apps to reflect the abilities of users with subjective low numeracy. This research project was conducted in three phases. The initial research phases explore cognitive processing difficulties associated with subjective low numeracy. A series of interviews with subject matter experts and a desktop research activity aims to identify pain points and problems hindering users from carrying out banking tasks efficiently and confidently. Phase two involved ideating solutions based on data collected in the first phase, focusing on developing a design system that is not dependant on traditional symbolic based number systems. After the ideation activity, the resulting prototyped solution is evaluated against traditional symbolic based systems by usability evaluation. The data gathered during this evaluation will provide insight into the performance of the systems and aids in any subsequent design iteration.

2 LITERATURE REVIEW

2.1 Defining Low Numeracy

Numeracy can be defined in two ways, mathematical skills, which are taught, and skills applied in everyday life [2]. Understanding a practical application of mathematical problem solving and having the necessary skills to apply it confidently define the core of numeracy. The Organisation for Economic Co-operation and Development reported that in 2016, 25% of adults in Ireland received a score lower than a level 1 in mathematical abilities, which ranks Ireland 18th for numeracy skills [3]. At this level of numeracy skills, performing anything other than basic arithmetic becomes difficult. Comparatively, at level 2, people possess the ability to process numbers in a relatable context where the mathematical content is explicit [4]. The results of the survey conducted in 2016 also indicated that the spread of mathematical skills was disproportionately spread across the different age groups. The lowest scoring age demographic was the 55-65 category. This may be attributed to the higher percentage of people who left school early in that age demographic. An average of 20.5% of people aged between 55-65 only achieved a lower than secondary school level of education compared to the 20-24 age group where only 5% achieved a level lower secondary school level [5].

Research conducted by the Institute of Education London found that low numeracy is linked to these three areas of daily life [6].

- **The economic impact** - the impact on an individual's earnings, employment, and personal finances.
- **The social impact** - on adults' family lives and daily activities, on social capital and active citizenship; and criminal justice.
- **The health impact** - physical health, mental health, health literacy, and how people feel about their lives.

OECD also reported a correlation between low numeracy and a lower level of trust in others, as well as a low engagement in community activities and political process' [7]. However, a lower ability in numeracy has been noted to positively affect an adult's motivation and effort to learn and improve their numeracy [8].

2.2 Number Sense

There are several factors, which cause low numeracy. A common factor is a special learning difficulty in math's (SLDM) or developmental dyscalculia. A common characteristic of dyscalculia is a number sense deficit, which heavily affects a person's ability to learn arithmetic [9]. This deficit is identified as an impairment of the ability to process symbolic representation of numbers and their magnitude equivalent [10]. This impairment also heavily affects the ability to carry out estimation tasks [11]. Studies have shown a direct correlation between mathematical achievements and a number sense deficit [12]. As a result of this, a person's ability to confidently and successfully perform everyday numerical activities can be limited [13]

2.3 Low Numeracy's Comparability to Subjective Low Numeracy

The challenge of adult low numeracy is identifying a number sense deficit or other factors that impact numeracy skills [14]. To help to identify low numeracy, experts often use scales such as the Lipkus numeracy scale to gauge the level of numeracy skills [15]. This scale is calculated based on an objective numeracy test. These objective measures have been a critical indicator quantifying numeracy skills, but there have been comparable success using subjective numeracy measures. The Subjective Numeracy Scale (SNS) test differs from a traditional objective test, as it involves a self-reported measure of perceived ability to perform mathematical tasks [16]. The SNS test is also faster to complete and evokes fewer adverse reactions, which encourages participation more than the objective numeracy test. A study conducted in 2007 aimed at validating the subjective numeracy scale compared to the objective one showed that the SNS scale held up considerably well compared to the established objective numeracy measures [17]. It also provides some additional qualitative improvements to traditional objective tests. As a result of this, the comparability of the SNS to traditional methods of predicting numeracy abilities allows for an alternative way of qualifying the intended user group for this project [18].

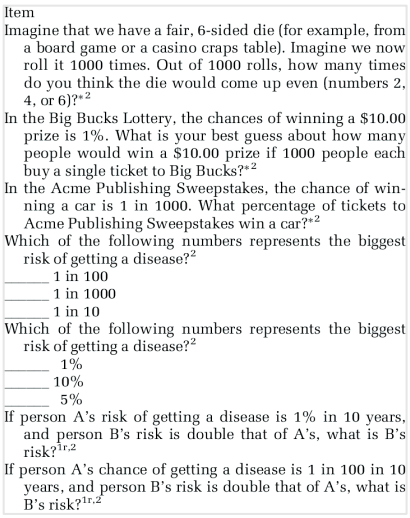

Item
Imagine that we have a fair, 6-sided die (for example, from a board game or a casino craps table). Imagine we now roll it 1000 times. Out of 1000 rolls, how many times do you think the die would come up even (numbers 2, 4, or 6)?*2
In the Big Bucks Lottery, the chances of winning a $10.00 prize is 1%. What is your best guess about how many people would win a $10.00 prize if 1000 people each buy a single ticket to Big Bucks?*2
In the Acme Publishing Sweepstakes, the chance of winning a car is 1 in 1000. What percentage of tickets to Acme Publishing Sweepstakes win a car?*2
Which of the following numbers represents the biggest risk of getting a disease?2
_____ 1 in 100
_____ 1 in 1000
_____ 1 in 10
Which of the following numbers represents the biggest risk of getting a disease?2
_____ 1%
_____ 10%
_____ 5%
If person A's risk of getting a disease is 1% in 10 years, and person B's risk is double that of A's, what is B's risk?1r,2
If person A's chance of getting a disease is 1 in 100 in 10 years, and person B's risk is double that of A's, what is B's risk?1r,2

Figure 1. Example of Lipkus and others subjective numeracy test

2.4 Improving Numeracy in a Financial Context

There are many teaching techniques to assist mathematical learning and numerical comprehension, which affect the ability to tackle numeracy conceptually. This involves putting numbers into a meaningful context and building upon previous knowledge. Identifying the most appropriate method for individual problem solving and

encouraging analysis of mathematical misconceptions has been highlighted as successful methods of improving numeracy skills [8]. Establishing non-conventional methods of comprehending arithmetic, specific to each person's case, can equip them with the necessary skills to carry out effective number processing [19].

The My Money Counts [20] project conducted by the Institute of Art, Design and Technology (IADT) is an example of these teaching methods applied in a financial context [21]. Designed to facilitate learning practical and sensible money management skills, the My Money Counts tool aims to support personal safety and independence. This project was a collaboration between Saint John of God Carmona Services and MABS (Money Advice and Budgeting Service). It was primarily focused on educating and supporting people with intellectual disabilities. The tool consists of 10 units ranging from understanding money, what is it, where it comes from, and what it is used for, paying for banking, and shopping. Each unit has guidance for the facilitator, as well as interactive games and exercises for participants. This tool is an excellent example of the application of teaching methods, which addresses understanding money and improves numerical comprehension in a financial context. Yo-Yos [22] is also another money management tool aimed at young people. This money management tool mainly focuses on money management education and does not focus on conducting numerical tasks.

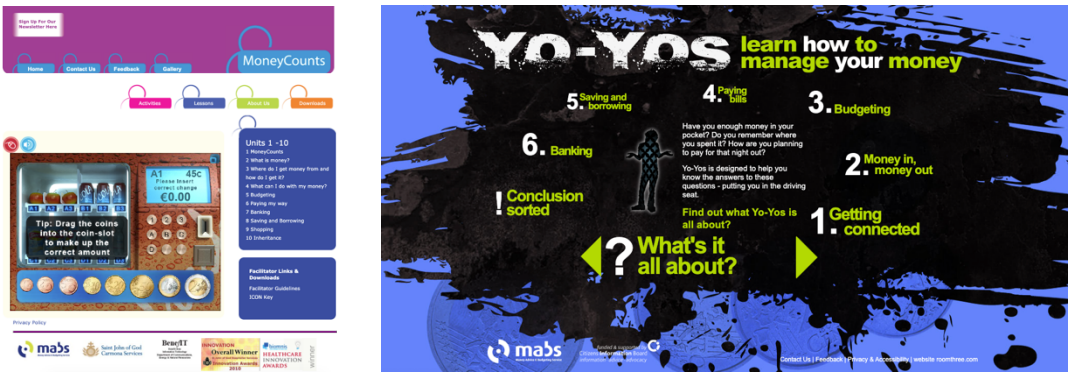


Figure 2. MyMoneyCounts.ie and Yo-Yos.ie

2.5 Mobile Banking Apps

Consumer transactions have vastly changed over the recent years thanks to an increasingly digital market. More and more people are interfacing with services through smartphones, and banking services are at the forefront of this societal change. Financial technology, or FinTech, has widely been adopted by banking customers, with more people using Mobile Banking (MB) than going to the bank or ATM to conduct financial transactions [23]. In 2017, 58% of the Irish population [24] used MB, and this figure is expected to reach over 70% by 2024. A study conducted in 2017 explored MB user's satisfaction by researching two key questions; Are users more satisfied with system functionality and usability, or are users more satisfied with MB for their convenience, social influence, better performance, or customer support [25]. The study results provided an insightful outlook on user adoption rate and adaptive rate. Highlighting the importance of combining an information system (IS) success model with a unified

theory of acceptance and use of technology (UTAUT) model to provide a robust measure of understanding MB usage.

A series of interviews conducted for a case study on daily MB showed the key aspects for a user while mobile banking are:

- A clear and straightforward view of balance entering and leaving the app
- Information on operational costs and the length of time of each step during wire transfers
- Managing a budget(s) but do not want to put too much effort into each task. It is not about having a specific, strict budget to respect each month but rather about saving any excess
- Understand the financial activity of their account in a simple and visual way

These themes, which were identified from the analysis of the interview results, highlight the user needs for everyday banking [26]. Although the survey result provided insightful information on MB use, it fails to consider the users' skills and ability. Most MB service providers have taken a one-size-fits-all approach, which does not work well for differing user needs [27]. Innovative MB apps, such as Revolut [28], tailors the user experience design for their primary users, which in most cases, have a high level of numerical competence.

Low numeracy skills can lead to several financial difficulties when conducting everyday banking tasks. To date, there are no MB apps that genuinely reflect the abilities and needs of users with low numeracy or subjective low numeracy. Financial mistakes, overspending, fraud and other financial vulnerability are all issues, which face users with a lower level of numeracy skills. A refined understanding of low numeracy users and how they interact with MB services is key to providing assistive features within MB apps. Studies have shown the benefits assistive technology can have when assisting users with cognitive impairments to make better decisions [29]. To facilitate this in a MB context, the design must utilise evolving features such as visual displays, error prevention, and intuitive interaction design principles. Tailoring these design aspects to better reflect users' cognitive processing abilities with a lower level of numeracy would provide a wide range of benefits. Designing these features with a better understanding of users with low numeracy could create alternative systems that do not require a moderate to high numeracy ability.

2.6 Alternative to Symbolic Base Number Systems

Mathematical learning apps mainly train the user's ability to compare numbers and their magnitude more efficiently. An interesting area of design has aimed to combine the symbolic and visual (non-symbolic) magnitude aspect of numbers. FatFonts is a novel visualisation technique, which combines these two aspects of numbers. [30]. The visualisation has been designed based on Arabic numerals but influences other numerical systems such as a unary and roman. This work was targeted at presenting sizeable numerical data sets, such as scalar fields, but has some interesting aspects that impact number processing. The multi-digit system seen in Figure 4 uses containment and scaling to present the symbolic representation of the 489 with an additional magnitude context. Using the critical design decisions and concepts used in FatFonts would provide the basis for bridging the gap between the symbolic representation of a number and its non-symbolic.

Figure 3. 489 presented in FatFonts

3 RESEARCH OBJECTIVES

Many leading mobile banking apps attributes their success to a User-Centred design approach (UCD), focusing on users, tasks, and use environments [31]. Although most users have experienced the benefits of improved mobile banking services, users are not provided with an alternative system for performing numerical tasks. Mobile banking app features fail to provide an inclusive method of performing a numerical task for users with subjective low numeracy. Offering choice for conducting tasks is a crucial principle behind inclusive design [32]. The goal of this research will focus on developing and evaluating an alternative to traditional numerical design systems used in a mobile banking app. Evaluation will be carried out using the USE questionnaire. This subjective usability measure focuses on four critical aspects of usability: Usefulness, Ease of Use, Ease of Learning and Satisfaction.

To achieve this, there will be three key questions. The research questions posed are:

1. Do individuals with low SNS scores report higher usability with the informed non-symbolic design system compared to a traditional design system?

2. What are the usability and satisfaction issues relating to the informed non-symbolic design system?

Three hypotheses will be required to test research question 1:

H1: There will be a difference for the participants on their USE scores depending on the condition (non-symbolic design system compared to a traditional design system) to which they are assigned.

H2: There will be a difference for the participants on their USE score depending on their subjective numeracy group (low- medium, medium-high)

H3: There will be a significant interaction between the assigned test condition and numeracy

4 RESEARCH METHODOLOGIES

The research activities conducted during this project were structured around a UCD approach. This approach focuses on involving and designing for the indented users and their need's [33]. The research framework is structured around three phases, first to explore the user's needs and define their problems. The second phase to synthesize and refine potential design solutions, which address the user needs specified in the first phase. And the goal of the final phase is to validate the design solution with the intended users. Before any research activities were conducted, an ethics form was submitted and accepted for ethical approval.

The first iterations of the design system will be informed by primary and secondary data gathered in the project's first phase. The primary research methodologies conducted during the first phases of the project were a series of semi-structured Subject Matter Expert (SME) interviews and a user survey on MB. The secondary research activities were made up of an initial literature review, followed by competitor analysis and task analysis of other MB apps.

Figure 4. represents the timelines of research activities conducted throughout the project. Table 1 contains a description of each of the primary research activities.

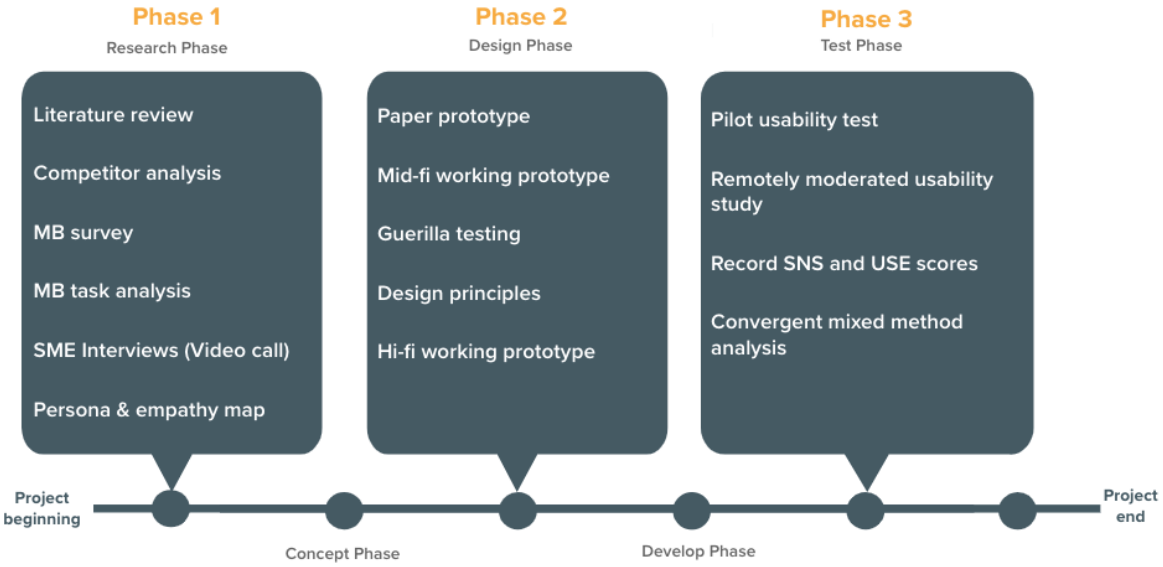


Figure 4. Research Activity Timeline

	User Survey	SME Interview	Guerilla testing	Usability study
Participants	60+ (as many as possible)	2 (SNA, Education specialist)	20 x 2	40 (Mix of age,sex and numeracy abilities)
Measures	Likert scale, single answer & free text	Qualitative questions	Task time, success rate, and Qualitative feedback	SNS and USE
Analysis	Cross tabulation and chi-square analysis	Thematic analysis	Issue prioritization analysis	Convergent parallel mixed method analysis

Table 1. Primary Research Activity Details

4.1 Phase 1 – Competitor Analysis

Nielsen's ten heuristic principles provided the analytical framework for analysing other MB apps [34]. Five mobile banking apps and one budgeting app were analysed, these being;

- Bank of Ireland
- AIB
- Permanent TSB
- Revolut
- N26
- Spendee

For each of the apps, the features offered were recorded to identify which apps provide the most comprehensive MB experience. Particular attention was paid to identifying any assistive features, which may be implemented in these apps. After analysing each of the apps, none of the group had explicit numeracy assistive features. They did, however, have basic assistive features such as prevention of overspending more money than available in the account. Positive and negative aspects of the competitor apps heuristics provided insight into how MB apps are failing, or succeeding, at providing an effective MB experience (Figure 5.). Design insights and heuristic reports on each of the apps were a key input into the proposed design solutions overall design.

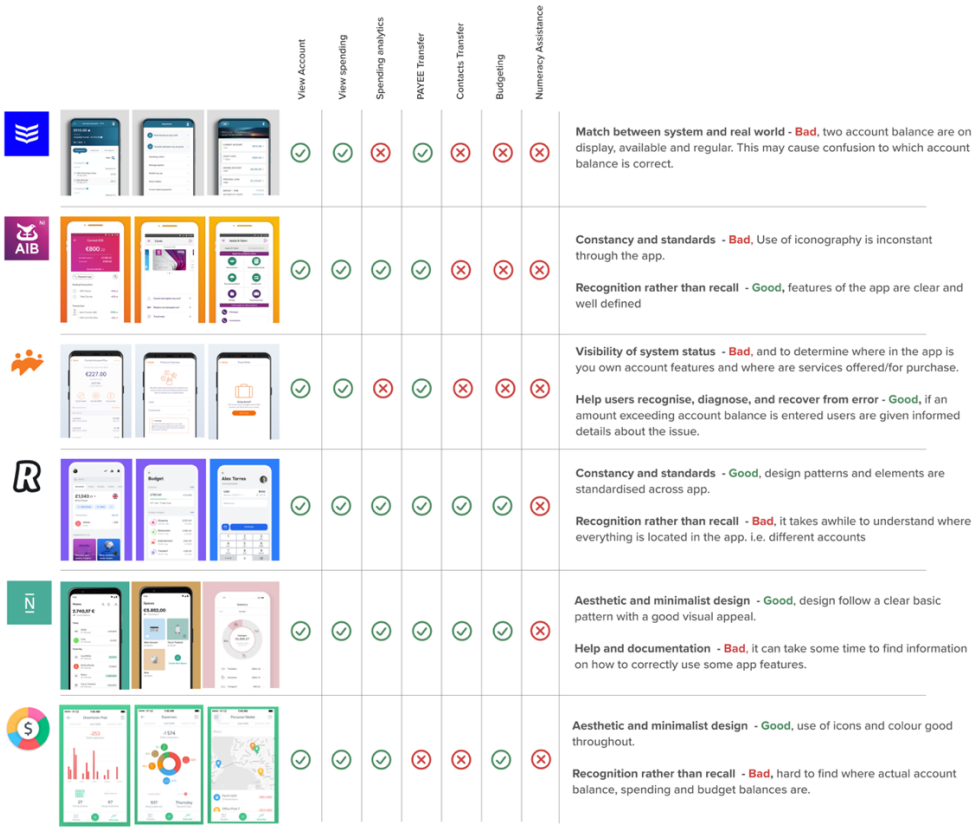


Figure 5. Competitor Analysis

4.2 Phase 1 – MB Survey

The first piece of primary research, the survey, focused on MB use to identify any correlations, which may exist between age groups, perceived numeracy ability, and technological confidence. The survey questions were structured around insights gathered from the literature review activity, with the hope of further exploring perceived numeracy abilities and the effect it has on mobile banking use. Microsoft forms was the tool used for creating the survey; then, it was reviewed by the research supervisor. Once accepted, the survey was then circulated amongst willing participants. The survey contained a series of Likert scales, single answer questions, and free text answers if required. Likert scale questions provided nominal scale measurements, which were evaluated using cross-tabulation analysis. Once the results were populated in a cross-tabulation table, a chi-square statistical analysis tested the statistical significance of the data (Appendix B). This determined whether the variables are independent or not. The analysed results were a key input into the second design phase, with the intention of ideating potential design solutions based on insights gathered post-analysis.

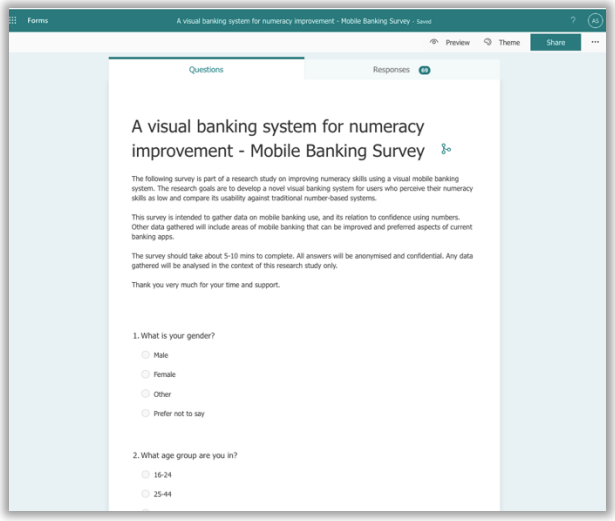


Figure 6. Mobile Banking Survey

The results of the survey can be seen graphed in Appendix A. The participant demographic was generally split evenly between male and female, and the two age categories of 16-24 and 25-44. The older two demographic groups were not as highly represented as the other groups. 60% of participants indicated they use mobile banking 1-5 times a week, and 47% of participants often use online banking to transfer money or pay a bill. A cross-tabulation analysis revealed that the participants who reported a lower mean SNS score were less likely to have indicated a number-oriented subject as their preferred subject in school. Another cross-tabulation analysis between negative emotions that occur while online banking, and mean SNS scores, revealed a spread of negative emotions across reported mean scores—suggesting that negative emotions, which may occur while online banking, may not necessarily be linked with numeracy ability. Further analysis of the qualitative feedback received highlighted negative emotions originate from fears of online scams and security breaches. Other negative emotions come from viewing the overall bank account balance in relation to spending and fund availability.

Another critical insight provided by the survey results was the low confidence scores reported for online budgeting. This may indicate why managing a budget was rated the lowest when participants were asked to rank their online banking use.

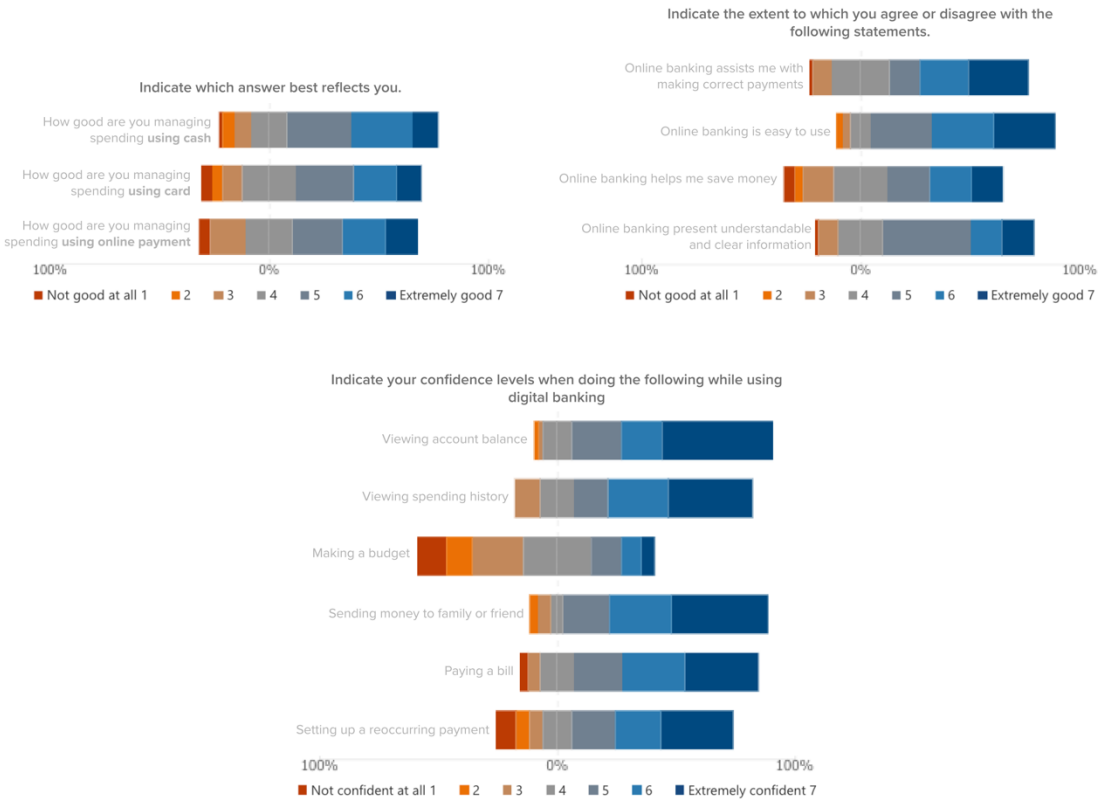


Figure 7. Graphed Survey Results

4.3 Phase 1 – SME Interviews

Subject matter expert interviews were the second primary research activity conducted in the first phase of the project. These interviews aimed to investigate any additional aspects of numeracy skills, which could not be obtained using other research methods due to ethical implications. The results of the interviews highlighted the challenges facing people who struggle with using numbers and techniques used to overcome these difficulties. The participant recruitment for these interviews resulted in one secondary school Special Needs Assistant and an Early Educational development expert. The interviews were conducted over video call to mitigate any Covid-19 exposure risks. A theoretical framework was established using the literature review as an input before the interview. A deductive approach allowed an exploration of preconceived themes identified during the desktop research phase. Post-interview, the results were coded accordingly for analysis. The interview structure took a flexible approach, allowing participants to feel open about the questions and explore interesting comments during the interview [35]. These interviews were primarily focused on gathering qualitative data. The method used for the analysis of the qualitative data gathered followed an inductive approach. A thematic content analysis removed any biases and collected general themes within the data [36]. Identified themes were compared against existing secondary research to verify the validity of the themes identified within the data gathered from the interview.

The first interview was carried out with an early childhood development expert. Qualitative data gathered during this interview had a strong theme of techniques and activities used to improve early mathematical development (Appendix D). The primary methodology used was a sensorial introduction to numbers and mathematical tasks focusing on tailoring activities for cognitive development. This tactile approach to number interaction allows students to physically manipulate numbers to tackle number problems and understand their magnitude equivalence.

Figure 8. Example of Early Education Instruments for Teaching Maths

The other SME interview carried out was with a secondary level special needs assistant. The first method identified in assisting students with mathematical tasks was building upon their current knowledge base/ability. This involves highlighting connections between what they currently know and how it can be applied to other mathematical tasks by breaking down the processing procedure. See Appendix E. One other aspect of this method, which is used to assist this understanding, is applying mathematical tasks within an everyday context. The example provided during the interview was examination results and their percentage calculations. Students could relate to this context, which would drive them to consider aspects of the task, which need to be understood before beginning the task.

The final collated results of the SME interviews provided more details on the key themes identified during the literature review, these being magnitude processing and meaningful context. The interviews allowed for a deeper exploration of how these principles are practically applied, focusing on assisting people in overcoming their impairments and improving their ability. The insights gained during the interviews were a key driver for the interaction and visual design of the prototype. Consideration was given to how these techniques can be integrated into a mobile banking context. In particular, the physical manipulation of numbers became an essential user

interface characteristic that was novel in its approach to financial management but reflective of number comprehension techniques.

4.4 Phase 1 – Persona and Empathy Map Development

The last research activity, which was conducted towards the end of phase 1 of the project moving into phase 2, was persona development and empathy map activity. The personas were reflective of research data acquired during the survey and SME interviews [37]. The goal of this activity will be to better define users and their characteristic, as well as being considerate of all potential users, no matter what their technical ability or use goals/expectations may be. To support user understanding, empathy maps were completed for each persona. This activity helped externalise what is known about users and created a better understanding of user needs, which assisted in the making of design decisions [38].

Two personas were developed, an older user, Mary, and a younger user, Brian. See Figure. 8. As these were developed, the activity was structured around reflecting insight gained from the survey to represent real users. Both of the personas would be considered to have a low – medium level of numeracy. These two different personas had the commonality of a lower numeracy ability. However, one was trying to send money, and the other was trying to create a budget, both using a mobile banking app. These two research activities were conducted before any design solutions were produced. They provided input into items that need to be considered while designing the interface and experience of the app.

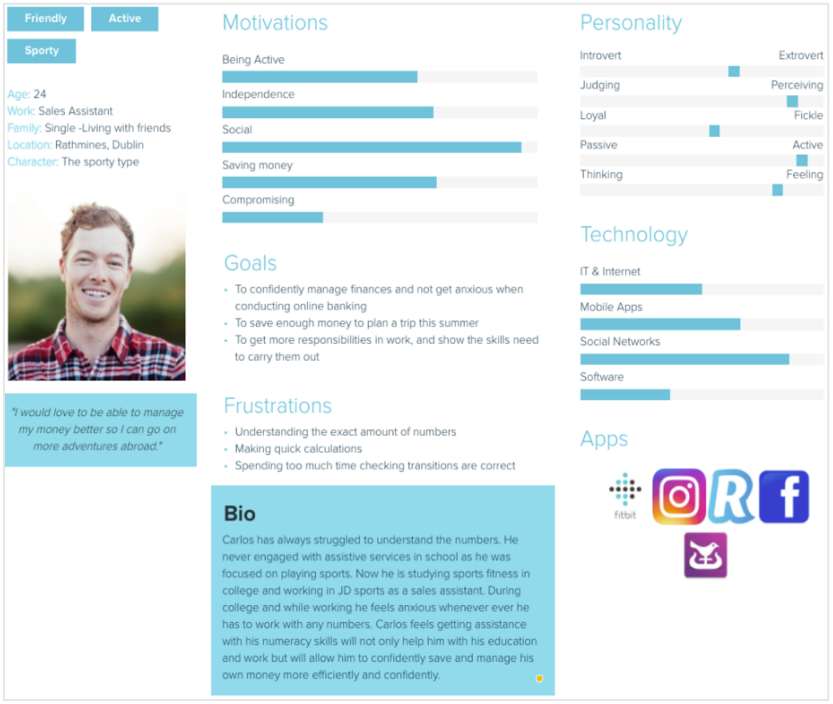
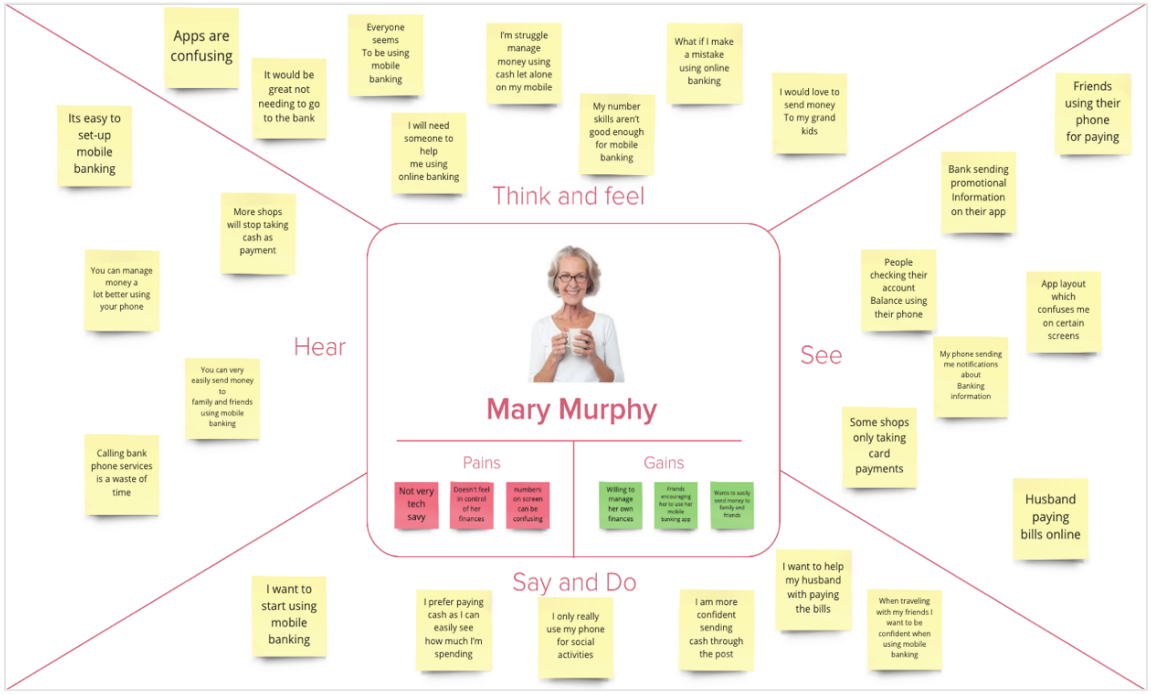


Figure 9. Personas



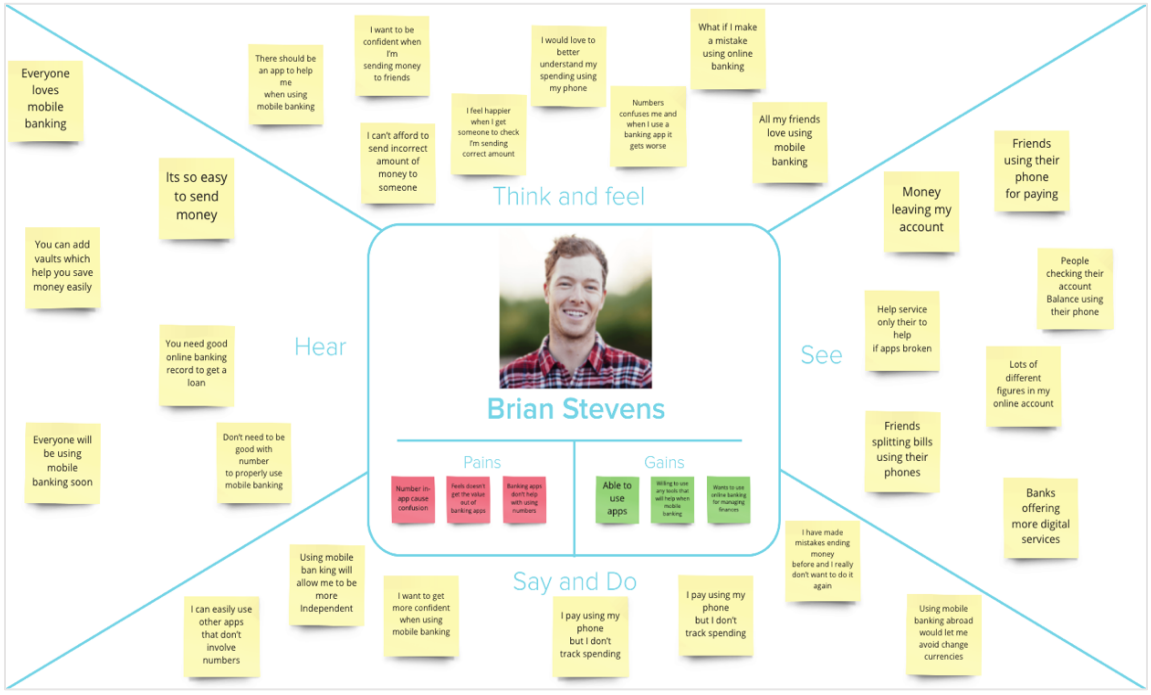


Figure 10. Empathy Maps

4.5 Phase 1 – MB Task Analysis

Using the persona and empathy map as an input, a task analysis with journey mapping features were created using Revolut and Spendee [28, 39]. In the task analysis, a reflective scenario was defined for each persona, and a user journey for both personas was recorded as they completed a task. For this activity, two participants were recruited and asked to complete the task. Before each task, they were provided with additional context and background on the persona they were acting as. This exercise aimed to identify pain points and insights for both of the personas and explore current app task flows. The intention was also to desensitize MB tasks for users who may struggle with numeracy abilities. The two assigned tasks focused on money transfer and creating a budget. These two tasks focused on the sending money feature in Revolut and the creating budget feature in Spendee. Analysing the two apps shows how different banks allow users to complete these tasks using their app [40]. The aim was to highlight the positive and negative aspects of MB tasks completion and the effect perceived low numeracy may have on completing these tasks. The learnings from this activity would be a key design input for the proposed prototype. Aspects of current apps, which work well, such as general navigation and visual appeal, provide a basis for the potential prototype. During each task, there were several areas, which need specific attention in the context of low numeracy. The sending money feature for Revolut, although very efficient, did not have consideration for users who may struggle with numbers.

An example of this is when the user types in the amount they want to send, the amount was not taken away from their balance before sending, requiring a moderate to high ability in numeracy to comprehend the amount left in their balance. It also did not provide a send confirmation, which could be a source of anxiety and worry for users who are not confident in their numeracy abilities. The Spendee create budget feature task flow was easy to follow, but the creation of a budget was purely symbolic based. It did not contain any visuals until post creation. Once created, the app did have an appealing visual break down of budget spending. The elements of both app features, which do not meet the abilities of the personas, are the key areas where the final proposed design solution will focus.

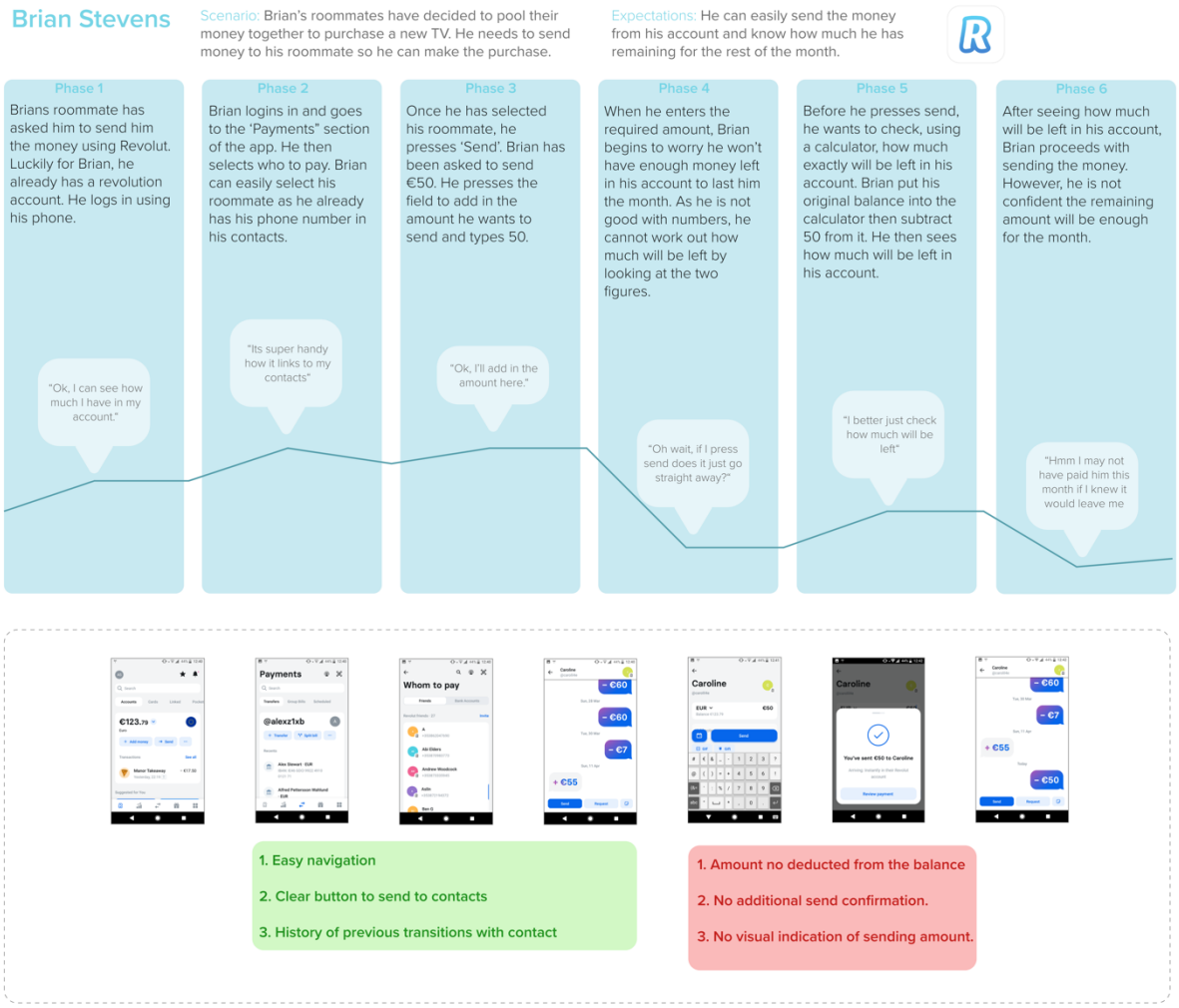


Figure 11. Brian Steven completing a task using Revolut

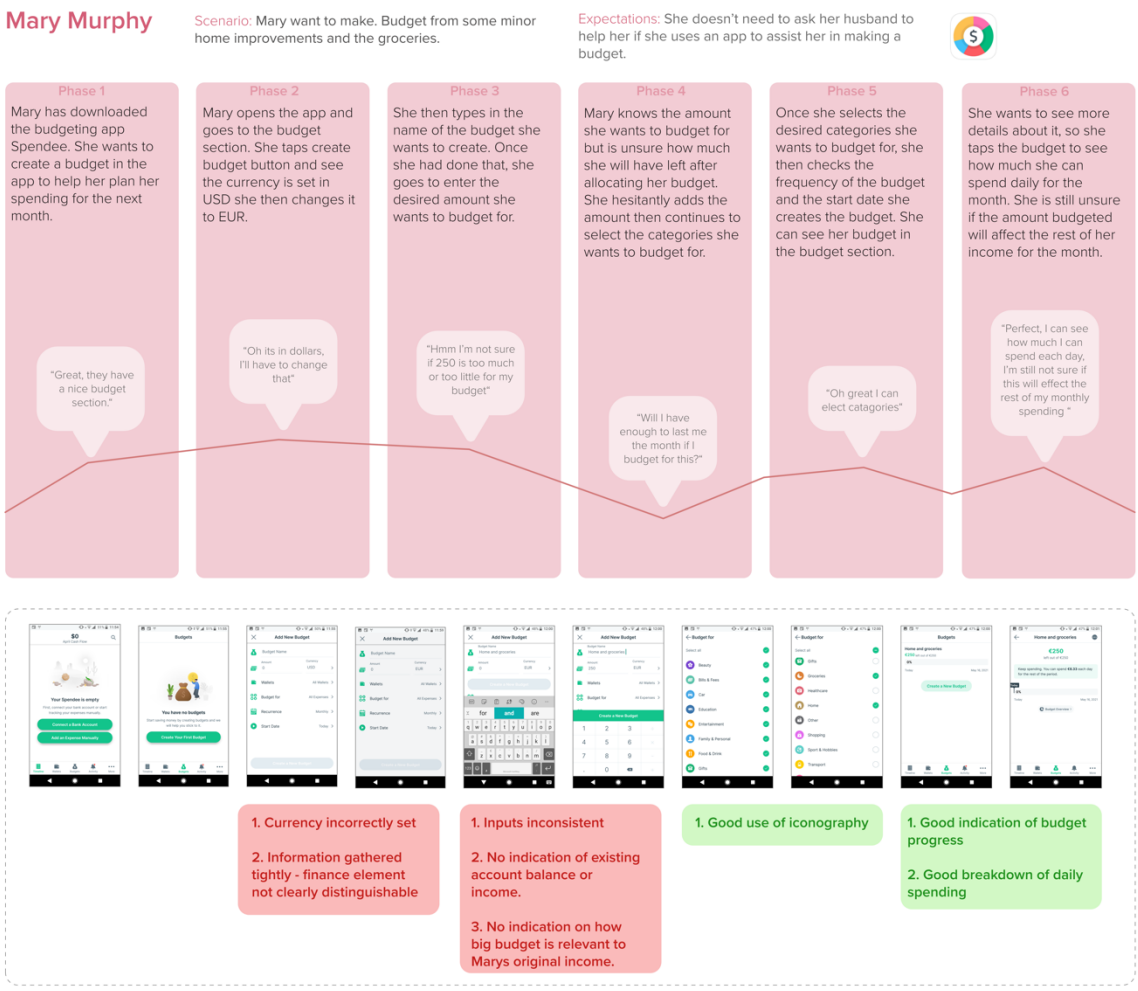


Figure 12. Mary Murphy completing a task using Spendee

4.6 Phase 2 – Guerrilla Testing

After the initial research conducted in phase 1, the data and insights gathered were used as design input into phase 2. Within this phase, the aim was to refine the MB design requirements for users with subjective low numeracy. Using these refined design requirements, a non-symbolic based number system was developed using Balsamiq, a lo-fi mockup design software. The goal of the lo-fi prototyping design system was to test the feasibility of the design variations. The lo-fi mockup user testing results can be found in Figure.16, located in chapter 5, Design. Once the scope of the lo-fi design had been narrowed through various iterations, the selected design was developed into a working prototype for a mobile device.

To gather feedback on each of the working prototypes, guerrilla testing was conducted with the prototype. Jakob Nielsen's guidance on guerrilla testing was the guiding framework for conducting this piece of research [41]. The test was structured around scenarios informed by the survey. Testing at this level allowed for an analysis of details within the design system, which can be iterated based on the selected scenarios. To assist with gathering feedback on the design, participants were asked to provide feedback on the prototype once they completed the tasks using the prototype. Data collected using this method was centred around the participant's thoughts while using the system. Task completion data, miss click rate, and time on tasks were recorded for each participant. These metrics provided the data for completing the issue prioritisation analysis. During the analysis, the successful or unsuccessful attempt at completing a task using the prototype will be evaluated against the task criticality, issue frequency, and issue impact [42]. Once the testing and analysis had concluded, the prototype was refined further. The second iteration of the prototype was created as a hi-fi prototype (Figure 13). The guerrilla testing process was then conducted in the same fashion as the first round of testing. The results of the second round of testing provided further feedback on the prototype. The feedback and data gathered informed the second iteration of the hi-fi prototype. This iteration was then refined to be used in the final usability evaluation.

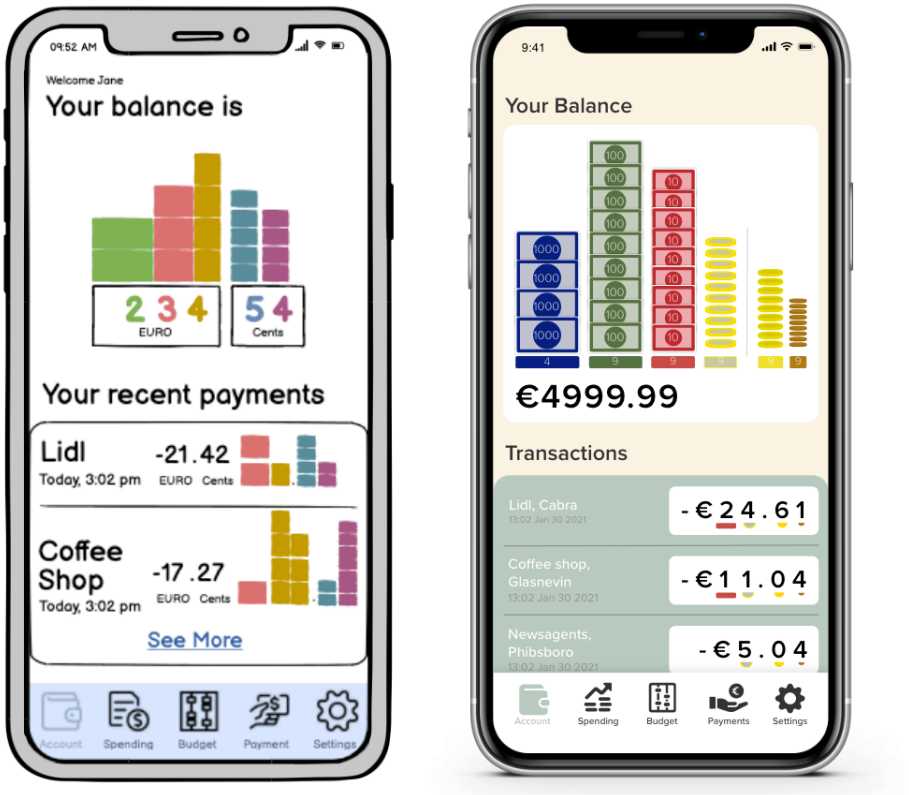


Figure 13. Lo-fi and hi-fi Prototypes used in Guerilla testing sessions

4.7 Phase 3 – Usability Study

Phases 3, the final phase of the project, was intended to address the research questions and validate or invalidate the hypotheses. To address these hypotheses, unmoderated usability testing was conducted remotely. The tool used for the evaluation was a user testing software called Maze, Figure 14. For the final study, two prototypes were produced: the visual non-symbolic prototype and the traditional symbolic prototype. The research supervisor was provided with the usability test protocol for approval. Once accepted, initial contact was made with potential participants. If interest was shown, they were then sent a link to a prototype where consent was managed. The link also contained the SNS questionnaire, prototype with missions, and finally, the USE questionnaire.

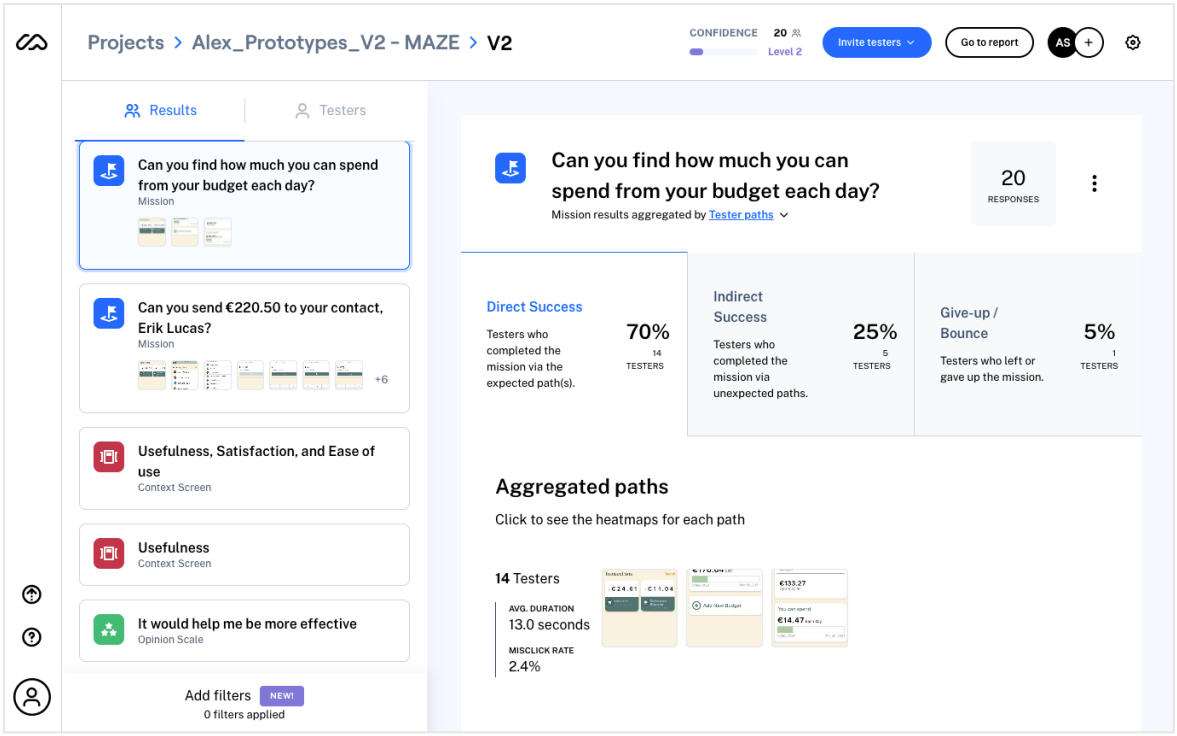


Figure 14. Maze User Testing Platform

The study was a between subject's design, with the protocol comprised of three main elements. The first required users to complete the SNS questionnaire. The second part asked users to carry a series of missions using the assigned design system. The final element required users to complete a USE questionnaire based on their experience completing the missions using the assigned prototype.

The study aimed to recruit 40 participants of varying age, sex and numeracy ability. Participants were assigned to one of two groups to test the first hypotheses. One group were sent the visual non-symbolic prototype and the

traditional symbolic prototype (similar to existing MB designs). SNS scores recorded were used to group participant into two groups, low-medium SNS score and medium-high SNS score. This was required for analysing the data so the first research question and the second hypotheses could be adequately addressed. The questionnaire used to calculate SNS scores was developed to reflect other questionnaires used in this field of study. The Likert scales used to record subjective numeracy consisted of 8 questions: 4 on perceived numeracy and 4 questions on preference for number use.

The independent variables of the study were two design systems used and participants SNS scores. The dependant variable was the recorded USE scores of each design system. This subjective usability measure focuses on four key aspects of usability: Usefulness, Ease of Use, Ease of Learning and Satisfaction. The USE questionnaire was developed around each design system focusing on the usability elements associated with numerical MB tasks. The questionnaire was primarily made up of 7-point Likert scales with the addition of two free text fields. This allowed users to provide feedback on the most positive or negative aspect of the design.

Once the study concluded, all aspects of the study design and results were used to evaluate the hypotheses posed. To complete this activity, a convergent parallel mixed-method analysis was conducted. For the quantitative data, a paired samples t-test was conducted. To interpret the raw data: the mean, standard deviation and plot chart were produced. The data was analysed using IBM SPSS statistical analysis tool. For the qualitative data gathered, the data was initially consolidated for better interpretation. When this had been completed, a thematic analysis was used to analyse the data further. Following the quantitative and qualitative data analysis, the results were compared for any relations. This approach provided the methodologies and structure required to prove, or disprove, the posed hypotheses.

5 DESIGN

Once the pre-design research activities conducted in phases 1 had concluded, the insights and data gathered during this process became the design input to the lo-fi digital prototype. The first iteration focused on the task completion flow, information architecture, and integration of the novel visual number interaction system. The navigation of the app follows other well-established apps like Revolut, with a bottom bar navigation feature. Each section of the app has an information hierarchy, which also follows other similar finance management apps. The number system interaction, and visual display, was developed with a focus on use within a mobile context. This was to ensure the feasibility of the system due to the screen size constraints. A block type number display was developed by taking influence from the physical manipulation of numbers and the visual representation of magnitude. This also involved the manipulation of finance amounts by touch and moving. This reflects the sensorial number experience used to assist number comprehension during early childhood developmental phase. This system intended to provide a number management interaction, which allowed users of a wide range of ability, conduct the basics of number tasks.

5.1 Lo-fi Prototype Iterations

The system primarily takes inspiration from a number abacus and number rods used in number activities aimed at number magnitude processing improvement and comprehension. The visual money blocks represent the various amounts,s, i.e. thousands, hundreds *Etc*. The users are required to press and drag the desired amount they wish to budget for or want to send. See Figure 15. This interaction is intended to represent the physical manipulation and placement of finances. The first iteration of the prototype was presented to a low numeracy accessibility expert for their review. The two design aspects, which were highlighted for improvement, were the colouring of the number blocks and the use of iconography. Considering this feedback, a second lo-fi iteration was produced to incorporate these suggestions into the design.

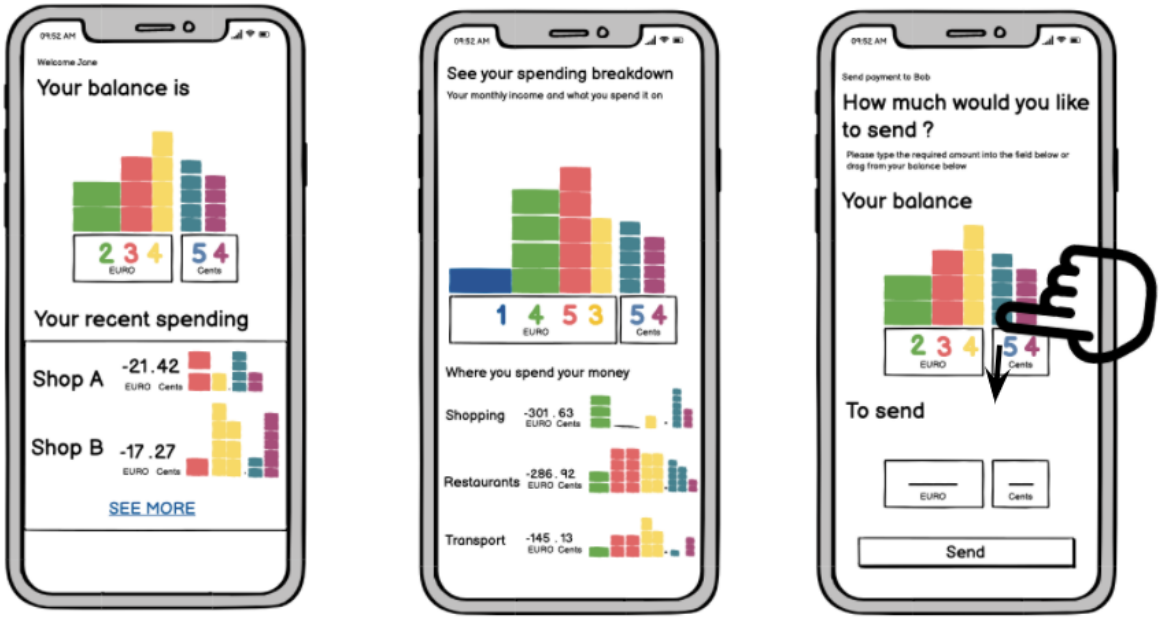


Figure 15. Lo-fi interactive prototype

The design of the prototype was centred around five primary features common in mobile banking apps, as identified during the user survey research. These being;

- Viewing balance and previous transitions
- Viewing total spending per categories, i.e., groceries, restaurants, *Etc*.
- Creating a budget
- Viewing details of a budget
- Sending money to contacts

Although the creating budget feature was not explicitly mentioned as a key feature for users during the survey, the inherent difficulty managing finances with low numeracy drives this feature. It also provides a route to better financial management, which has always been difficult for people with low numeracy [43].

5.2 Lo-fi Prototype Testing

For each prototype feature, the desired task flow was defined within the lo-fi prototype, and missions were created for user testing. Participants were asked to complete the following missions:

1. Can you find your transactions from yesterday?
2. Can you find how much you spent in December, in restaurants?
3. Can you create a budget of €250 for Groceries and House, occurring monthly?
4. Can you find how much you can spend from your budget each day?
5. Can you send €120.50 to your contact, Ben Simon?

The user testing was conducted with 20 applied psychology students using the remote user testing software Maze. The desired interaction of pressing and dragging the money blocks transpired to be impossible with this software. Because of this, the interaction was changed to clicking/pressing on the blocks to add them to their budget or amount to send. Before the session began, students were provided with the project background and then they were asked to complete the missions using the lo-fi prototype. After each mission, students were asked to provide feedback on the features and the usability of the prototype while conducting each mission. Once they were finished, there was a discussion about the prototype and a debrief.

The qualitative feedback obtained during this user testing provided an insight into the number systems performance. The primary theme identified related to the symbolic representation of the numbers. At first, users did not fully comprehend the meaning of the block, nor did they fully understand how to interact with them correctly. However, the feedback received suggested that once they understood the system, they could then successfully interact with the system. Recommendations from the group mainly focused on re-designing the number blocks to be more representative of money as opposed to ambiguous blocks representing numbers. The quantitative data gathered using Maze also backed up these key themes discussed post-testing. Heatmaps and miss click rates were also a primary indicator of areas within the lo-fi prototype, which performed well or not.

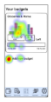
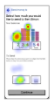
		Avg. success	Avg. bounce	Avg. time	Misclick rate	Qualitative feedback
	Finding how much was spent yesterday.	53.8%	28.2%	7.0s	4%	“had to look for a moment to see the “see more” option” “remove the “see more” button from under the module” “Originally clicked on payments at the bottom of the toolbar!”
	Finding how much was spent on restaurants last month.	85%	0%	8.2s	7.5%	“Was a bit of a guess, maybe changing wording to history?” “more icons I think” “I thought it would be on the same page”
	Creating a budget of €250 for groceries and home.	94.7%	5.3%	10.8s	10.9%	“expecting to just type in 250 into input box” “Little introduction so the user knows what is happening straight away.” “Not used to the blocks representing the amount for hundreds, tens etc”
	Finding budget breakdown.	100%	0%	8.2s	11%	“didn’t know where I was supposed to click. “Just saw the budget I had created and clicked it.” “I just kept clicking until I found it.”
	Sending payment of €122.50 to Ben Simon.	94.7%	0%	7.6s	6.3%	“Unclear how that the blocks had to be moved” “Make the contacts more spaced out” ”Choose amount of money is the same throughout the app.”

Figure 16. Lo-fi iteration user testing results

5.3 First Hi-fi Prototype Iteration

Taking both the qualitative and quantitative data gathered during the first round of users testing, the second iteration of the prototype focused on improving the interactive visual number system and moving the prototype version to a hi-fi design. The first design problem was focused on making the visual number system more reflective of real money. For this, a number of solutions were produced to test their feasibility. These solutions were then presented to a low numeracy accessibility expert who previously consulted on the project. Aspects of two of the design solutions were their preference. Post consultation, the two best features of the solutions were combined. This included a note type design with an inner circle, coins that were circular in form, as well as colours reflective of real money.

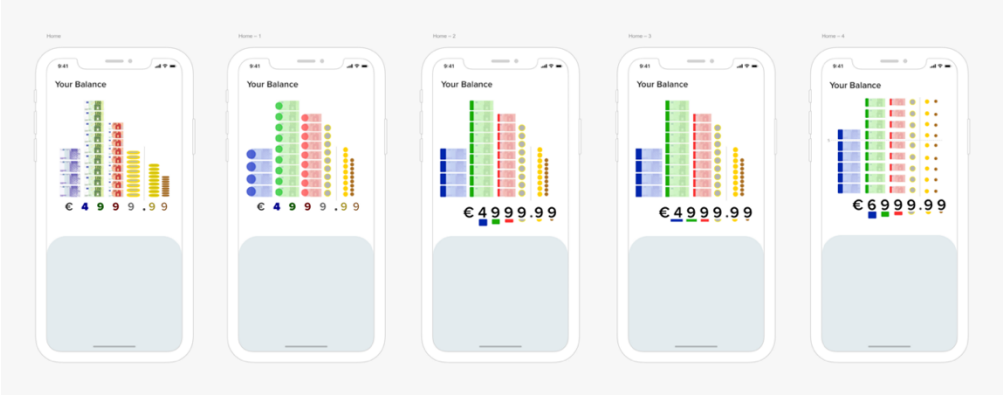


Figure 17. Visual Number Display Iterations

5.4 Design System

Once the visual number system and interaction had been decided, the following design task was to create the overall design system for the app. This design system included the font, colour pallet, iconography, and other essential user interface elements. The font used was a sans-serif font called Proxima Nova. There are three weights of this font used thought the app in several sizes. The lowest being the tertiary information supplement icons, at 10pt. The largest use of this font is the large titles at 24pt. Utilising sans serif font can aid in legibility [44]. For bodies of text, the sizing is essential for readability, comprehension, and recognition, with 18 points being optimal that allows for as much text as possible to be displayed [45]. The colour pallet was created and implemented throughout the prototype based on recommendation for designing material for people with learning difficulties. Implementation of a warm-toned colour pallet for a background can also help with reading performance [46]. This recommendation focused on reducing white space and the intuitive use of colour to make content more accessible. Another key design features are the interactive UI card layout used to section different pieces of information throughout the app.

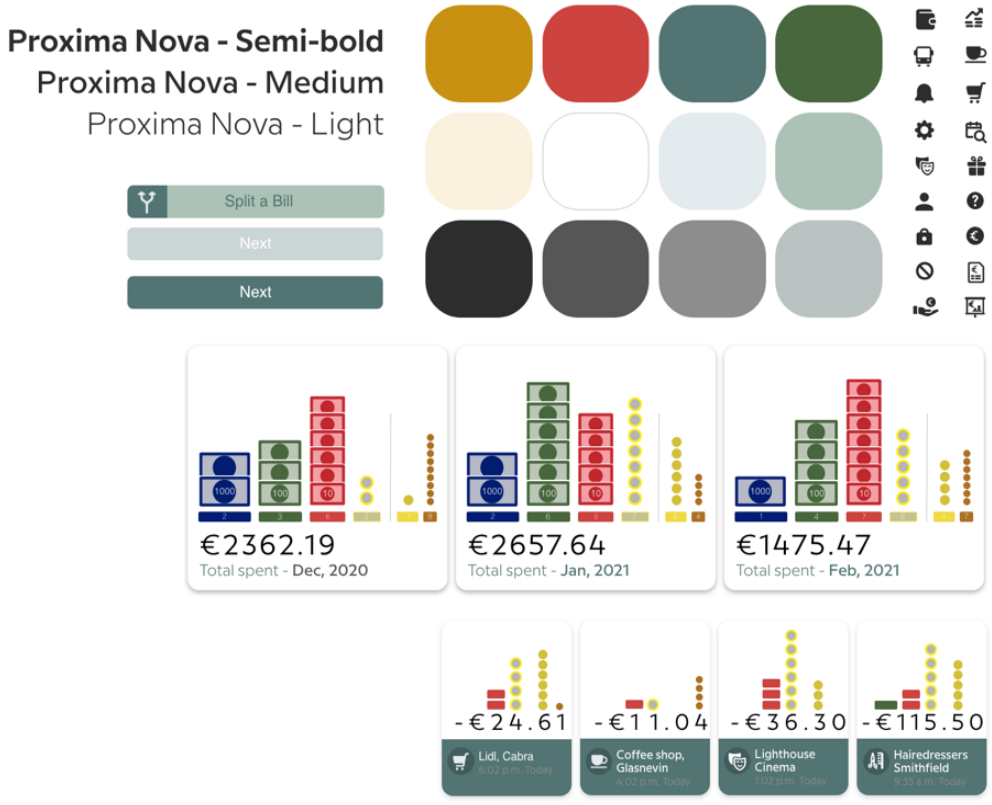


Figure 18. Prototype design system

5.5 Hi-fi Prototype Testing

Once the first iteration of the hi-fi prototype had been fully designed, the second round of user testing was conducted with another group of 20 applied psychology students. The user testing process was conducted as previously described. The data collected was also recorded in the same format was as before. The results of this round of user testing had three key themes, the first being the findability of certain information. Feedback received both during the debrief session and within Maze pointed to badly labelled sections within the app and confusing mission wording. These, in combination, gave the participants some difficulties. The two final themes identified during the testing related to the visual number system. Some participants indicated the interactive area in the prototype was not what they expected, as they pressed the top of the money stack. However, the correct interactive area was the bottom of the stack. The other issue was similar to previous issues seen in the first round of user testing, i.e. the intuitiveness of the required interaction when using the number system. Some participants recalled they initially pressed where the money should have gone, not where they were taking it from in the balance section. Other participants suggested they would have just preferred to have typed in the amount but did see the value for people who may struggle with numbers.

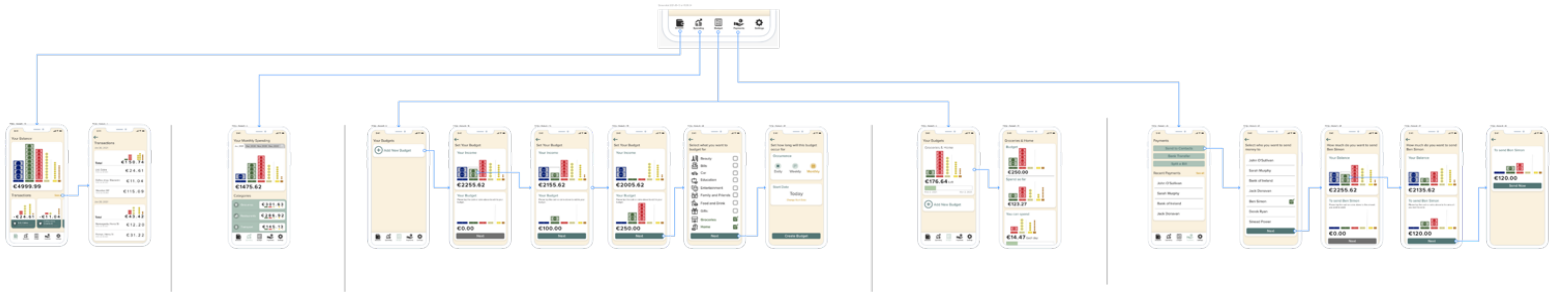


Figure 19. Navigation of hi-fi prototype first iterations

Taking all the feedback and data recorded during the second round of user testing, a final iteration of the hi-fi prototype was developed. The fundamental changes from the previous iteration were;

- Clearer icons and sections labelling
- Brief interaction instructions upon first use of the visual number system
- Rearrangement of screens within the create budget feature
- Additional clarification on the confirm sending screen
- Inclusion of avatar photos for contacts

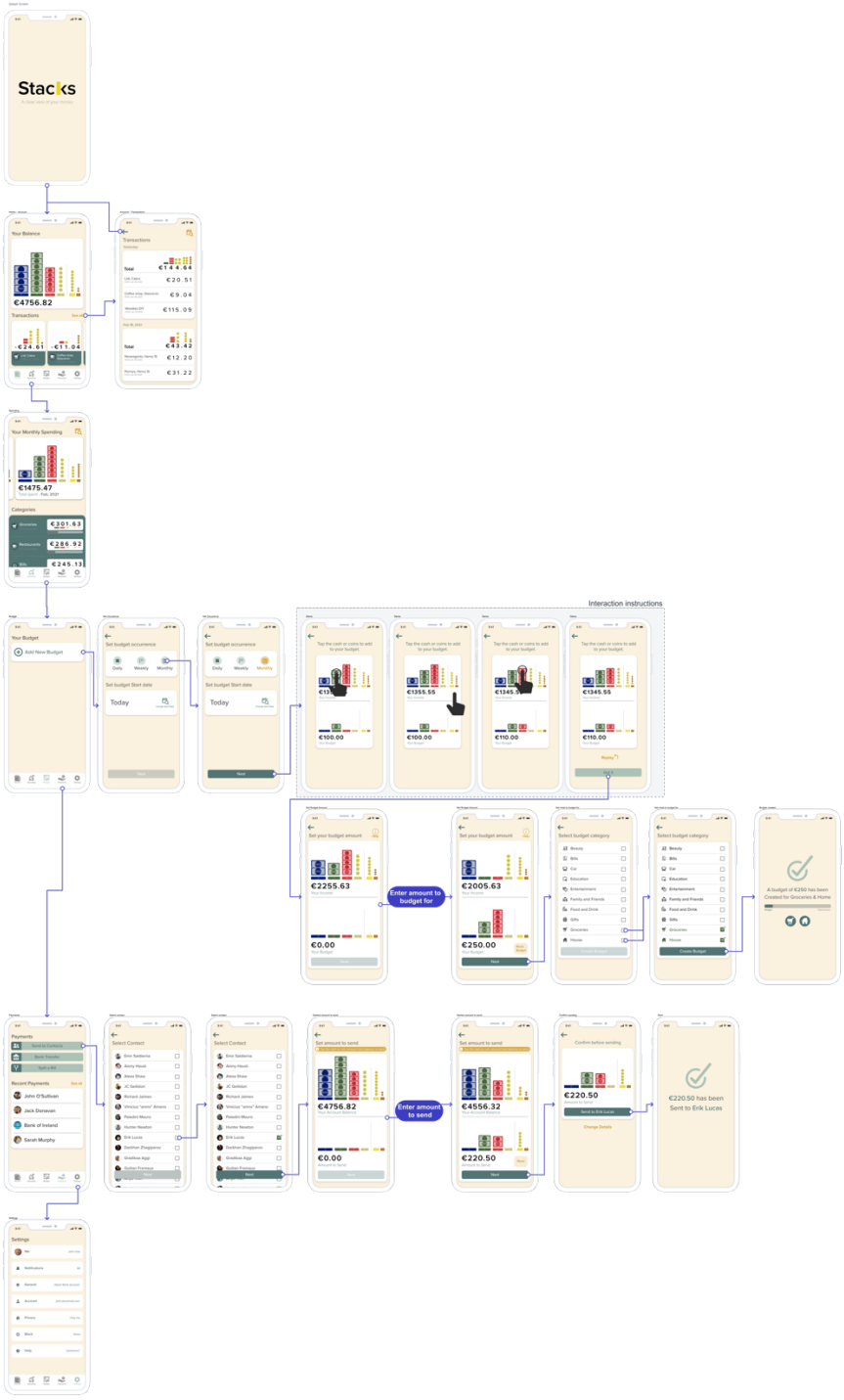


Figure 20. Final prototype

5.6 Final Hi-fi Prototype Iteration

Several micro-animations were also included in the prototype. The instructional content was also animated. These animations, however, were not enabled during the final testing due to the limitations of the user testing software Maze. The press and drag interaction was still not possible with the user testing software, so the financial interaction remained the same as the previous iterations, which was the click to add interactions. The animations, which were created in Adobe XD, the tool used to design the prototype, were not supported by the Maze plugin for Adobe XD. Interactivity required a user prompt. As a result of this, no automatic animations or actions were included in the final testing.

As the final usability study was a between-group study, two prototypes needed to be developed, the visual prototype and the traditional prototype. The prototypes were the same except for the inclusion or exclusion of the visual number display. The visual prototype contained the visual interactive system, which had been iteratively developed based on user testing and feedback. This solution had a visual representation of numbers as well as supporting symbolic representation, requiring users to tap numbers to add or subtract them when managing finances. The traditional system contained only the symbolic representation of numbers. The interactions were the same throughout all banking apps, requiring users to type in number amounts to add or subtract.

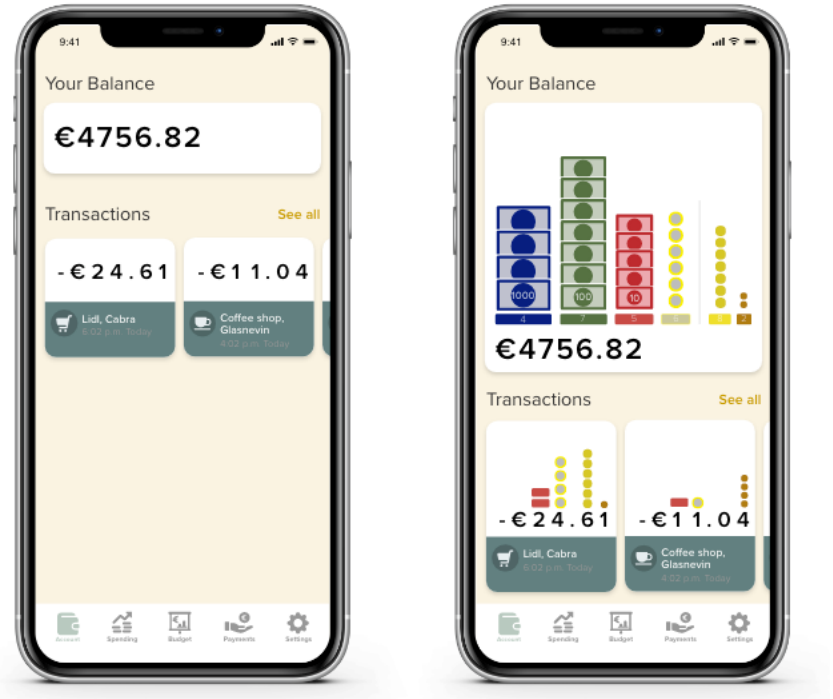


Figure 21. Traditional and Visual Prototypes

6 RESULTS

The study was designed to be completed by participants unmoderated. Each participant was assigned a test condition, the visual prototype or the traditional prototype, and was categorised into a Low-Medium, Medium-High group based on their SNS score. Both the test condition and the numeracy groups were the independent variables of the study. The dependent variable of the study was the USE scores. The USE questionnaire conducted collected both quantitative data and qualitative data. The quantitative data collected was statistical interaction information required to address the first research question and test the associated hypotheses. The qualitative data recorded in the USE questionnaire was analysed using thematic analysis to address the second research question. Figure 22 and 23 represent the age and education demographic of the participants who took part in the study.

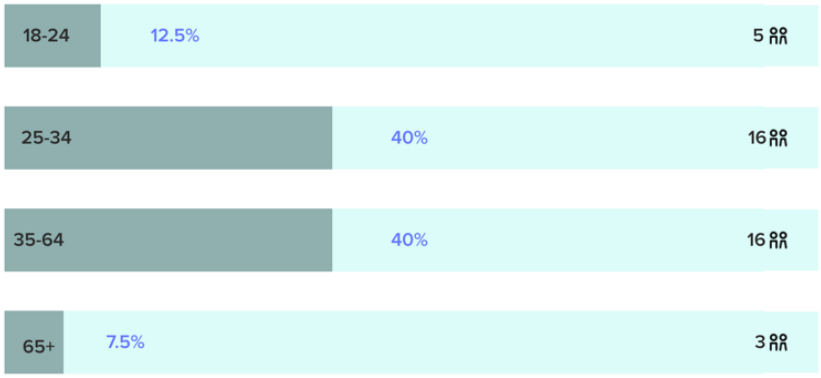


Figure 22. Age Demographic

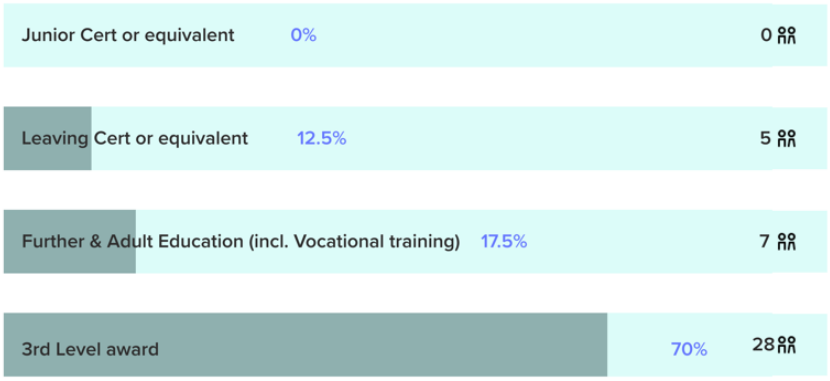


Figure 23. Education Demographic

Table 2 contains the mean, standard deviation and n values for the USE questionnaire grouped into the numeracy groups for the two assigned test conditions (visual prototype and traditional prototype).

Numeracy group	Test condition	Mean	Standard Deviation	N
Low-Medium	Visual Prototype	5.98	0.55	7
	Traditional Prototype	5.26	1.25	6
Medium-High	Visual Prototype	4.35	1.05	13
	Traditional Prototype	5.47	0.88	14

Table 2. Mean standard Deviation and n values

As the study design was a between-groups study, a 2x2 factorial between groups two-way ANOVA was conducted using IBM's SPSS, see Appendix H. This analysis aimed to examine any relationship between subjective numeracy and the recorded subjective usability of each prototype. To ensure the data assumptions were not violated during the study, both a Shapiro-Wilk test of normality and a Levine's test of homogeneity was conducted prior to analysis. See Appendix F. The results of the Shapiro-Wilk test revealed an acceptable distribution of data, while a test statistic of p=0.311 for Levine's test of homogeneity was recorded. This met the assumption of the homogeneity of variance. No outliers were reported in the SPSS output.

The first hypothesis associated with the first research question stated there would be a difference in the participants on their USE scores depending on their assigned condition. The statistical test used to prove this hypothesis recorded a result of $F(1,36)=0.388$, $p=0.537$, with an effect size of $n2=0.011$. These results support accepting the null hypothesis and rejecting the alternative.

The second hypothesis stated that there would be a difference in the participants USE scores depending on their assigned subjective numeracy group (low- medium, medium-high). This was proven to be statistically significant $F(1,36)=4.784$, $p=0.035$, with a reported power of 0.567. Thus, the hypothesis was accepted. Figure. 19 displays the difference in mean USE scores recorded between the two numeracy groups.

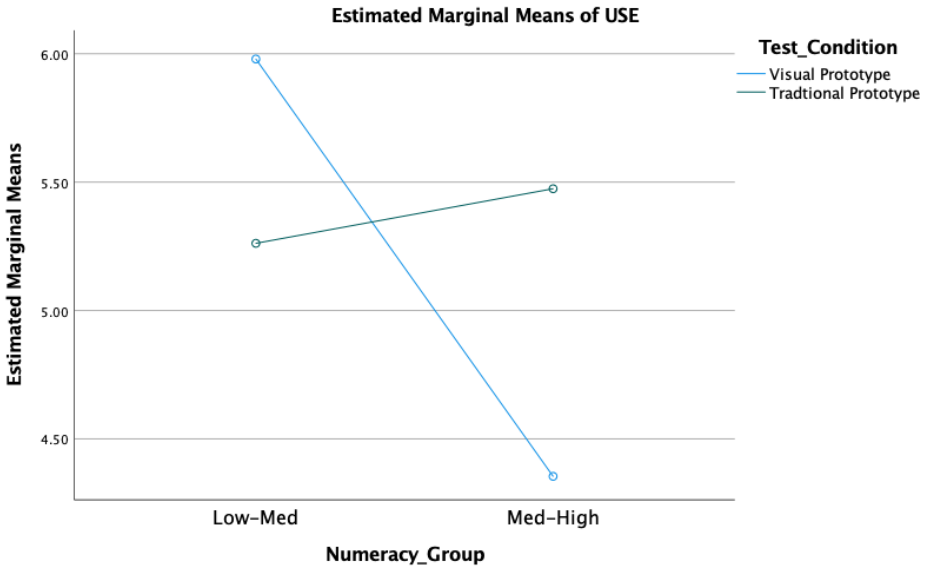


Figure 24. Estimated Marginal Means of USE scores

The third hypothesis stated that the interaction between the assigned test condition and the participants reported SNS would be significant. The statistical analysis reported $F(1,36)=8.097$, $p=0.007$, with a large effect size of $n2=0.184$. This result proved the level of significance required to accept the hypothesis.

The qualitative data collected using the USE questionnaire was used to address the second research question: what are the usability and satisfaction issues are relating to the informed visual design system. The data acquired were analysed using a thematic analysis to address the second research question (see Appendix J). The two open-ended questions presented to the participants during the USE questionnaire were: list the most positive aspects and the most negative aspects. The procedure used to conduct the thematical analysis first involved collating all data. The consolidated data were coded into themes relating to the positive and negative aspect of the visual prototype.

Three key themes were identified during the coding analysis for the negative aspect of the prototype, Design, Financial Interaction, and Cash & Coin Symbolism. Under these three themes, five subthemes were identified. The first three subtheme categories were related to design. These were; Layout/findability, feedback, and Colour scheme. The other two subthemes were associated with the Financial Interaction, and these were; speed and prefer typing. All subthemes were assigned to a parent theme due to their close relation and lower occurrence.

Four themes were identified in the analysis of the positive aspects of the visual prototype. These were: Financial Control, Budgeting, Visual Money, and Design. No additional subthemes were identified.

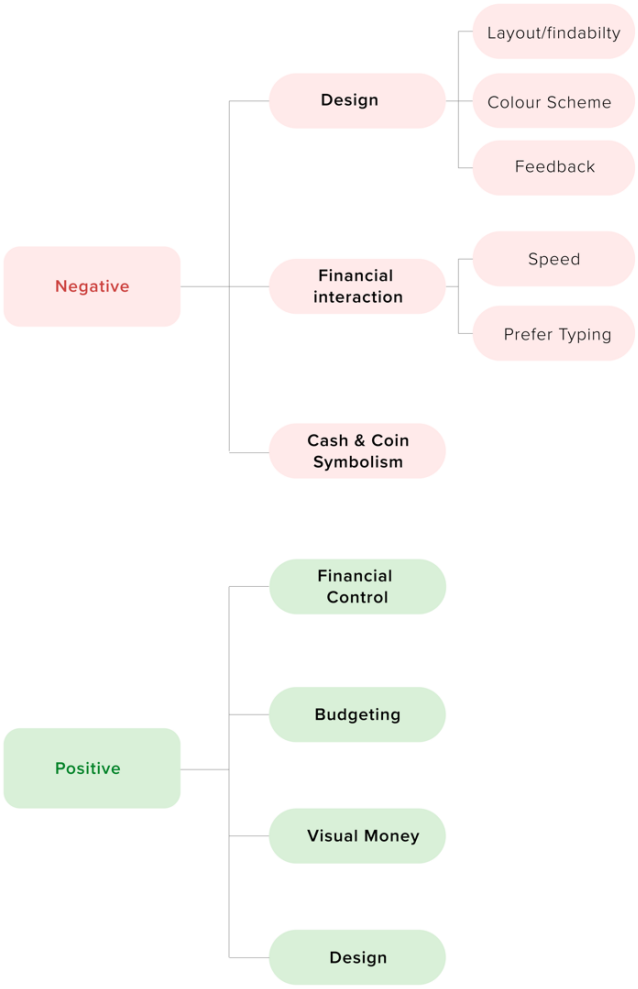


Figure 25. Hierarchy of positive and negative, themes and subthemes

Theme – 1 Design

Overall, eight references were made to the overall design of the prototype. These references refer to a number of aspects of the visual prototype UI/UX design, which were developed during the project's design phase. These issues did not directly affect the novel interactive numbers system but did have an overall effect on the prototype's usability. The three subthemes relating to the design were:

Subtheme – 1 Layout/findability

The feedback received suggested these issues were intrinsically linked, hence the amalgamation of these issues. Based on the results, the layout design of elements and features within the prototype affected the overall findability of certain UI elements and features.

"contact list was not alphabetical and should be able to view transactions from December on home page"
"a lot of big content on each screen, I did not know where to look"

Subtheme – 2 Colour Scheme

Two participants indicated they were not satisfied with the colour scheme used throughout the app. Additional analysis did not reveal if this had an impact on the usability of the prototype.

"The colour scheme was a bit off-putting at first"
"Could there be more friendly/inviting colour scheme"

Subtheme – 3 Feedback

Two instances of inadequate feedback were identified. The participants indicated they would expect additional feedback from the prototype. One of the participants indicated that this impacted their ability to complete the task correctly.

"I would like to have more feedback from the app."
"there was no feedback on the buttons I clicked."

Theme – 2 Financial interaction

The second key theme identified related to the interaction with the in-app finances and the visual display of money. Relating to this issue, two strong subthemes were identified, which made up all the relating issues.

Subtheme – 1 Speed

A number of participants indicated they were not happy with the speed at which they could complete the task. The feedback suggests some users felt the process took longer than they would have expected. There was one indication that the speed and input affected the usability of the prototype.

" I felt lost when I had to add money by clicking on the little notes. Adding number would be easier to use."
"I also feel like it slowed me down loads"
"Clicking repeatedly on coins is slow"

Subtheme – 2 Prefer Typing

Several participants suggested their preference would have been to type the number amount, opposed to using the novel interactive system.

"it takes longer to click on the money/ add it up than it does to type in the amount of money to send"
"Would prefer to type in numbers."

Theme 3 – Cash & Coin symbolism

The representation of money was identified as a prevalent theme during the analysis. Some participants did not fully understand the numbers display. This theme seemed to affect the user's ability to use the app intuitively at points.

"when you could see the 100 on the notes, but with the coins it was really confusing to know what their value was as the number actually meant"
"I was not sure which coins were represented by the dots"

Theme 4 – Financial control

Eight participants indicated that the visual prototype would assist them in exercising financial control. The feedback suggested that both the visual representation of money and the interaction required to carry out tasks would lead people to be more considerate about their financial actions when using the visual prototype.

"visualising my money that I have/ or have left. I think I can picture it better so I will probably spend less"
"It gives you nice control over your money with a tactical feeling"

Theme 5 – Budgeting

Seven individuals indicated they liked the budgeting feature. Although this relates to the previous theme of financial control, the seven individuals explicitly called out the visual prototype budgeting features as the most positive aspect of the prototype.

"the budgeting aspect is a great and easy way to save"
"The budget setup was nice"

Theme 6 – Visual money

A more significant number of participants referred to the positive effect visualising money had on their experience using the visual prototype. The feedback suggested that this both affected their experience but also their attitude towards making financial decisions.

"I like the way it's visual in taking money from your balance"

"I liked the ability to see my money differently"

Theme 7 – Design

Three participants indicated they were satisfied with particular aspect of the design. Although previously highlighted, certain aspects of the design were listed as negatives, some aspects of the design were noted as being positives. These being different from the negative listed suggested no conflict across participants.

"The clear way the app show spends on each category"
"the icons for the amounts of money going up and down"

7 DISCUSSION

The present study was designed to research the user experience of a novel visual interactive number system in mobile banking app context in relation to an individual's subjective numeracy. The approach focused on two main objectives: the exploration of differences between reported subjective usability of the visual prototype and the traditional prototype depending on participants' subjective numeracy level. The second objective was aimed at identifying any usability issues, which were associated with the visual prototype. The second objective was intended to identify issues, which require addressing in the next iteration of the prototype. However, it was also intended to identify areas of the current iteration which had a positive effect on the users' experience.

7.1 Subjective Numeracy and the Visual Prototype

Although the results of this study suggested a slight difference reported in the USE scores across both of the prototypes, there was a significant difference in USE scores compared to the assigned numeracy group. The Low-Medium numeracy group reported a significantly higher subjective usability score when using the visual prototype. In contrast, the Medium-High group reported a significantly lower usability score when using the visual prototype. Using the traditional prototype, the Low-Medium numeracy group reported a slightly lower usability score than the Medium-High group.

As defined by the Centre for Universal Design at North Carolina State University, universal design is "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [47]. Given this definition, the current version of the visual prototype cannot be in line with universal design principles due to the significant difference between the reported mean USE scores across the two numeracy groups. However, when considering the visual prototype in the context of the universal design principle of "Flexibility in Use" [48], the prototype does allow users with a lower numeracy ability to carry out financial tasks in an alternative method, which has not been previously offered in current banking apps. The result of the study also supported the impact this has on the overall usability of the prototype, as a significantly higher usability score was recorded in the lower numeracy group for the visual prototype.

While considering the effect that the assigned numeracy groups had on the usability score. However, subjective numeracy reporting is considered a good indicator of objective numeracy; there have been studies proving it is not always a precise indicator [49]. Even with the potential discrepancies, which may have occurred during the subjective numeracy reporting compared to a participant's objective numeracy, the study results still maintain that lower numeracy groups report a significantly higher usability score using the visual prototype. The unreliability factor in the subject numeracy reporting could have affected the overall reported usability scores reported for each of the prototypes, but not to the point in which the results of the study should be deemed invalid.

7.2 Reported Usability and Satisfaction of the Visual Prototype

Although the mean USE scores were relatively the same across the two prototypes, a thematic analysis provided an insight into the positive and negative aspect of the visual prototype. The biggest issue identified in the visual prototype was the financial interaction. There were two subthemes identified under this issue: the speed at which tasks could be completed and the preference for typing. These issues can be considered closely linked as to type in the numerical value would increase the speed. These two prevalent themes also indicate why the reported mean USE scores were significantly lower for the higher numeracy group. Using the MAYA (Most Advanced Yet Acceptable) principle as a guideline [50] when analysing the negative impact the visual interactive number system had on higher the numeracy group, it is clear the current skill set was not taken into consideration in the visual prototype. Nor did the design follow familiar design patterns as the visual numbers system was novel and did not have the desired interaction of a user with high numeracy.

Although the visual prototype was reflective of Jakob Nielson's heuristics design principle "Match between the system and the real world" [34] in the context of the money display, the principle "User control and freedom" was violated due to the fact that the design system was tailored specifically for users with a lower numeracy ability. Allowing the users to choose their preferred interactive system, whether it be the visual or traditional, would have addressed the violate principle and improved the overall experience for the higher numeracy group.

The primary positive aspect of the visual prototype, which was recorded across each of the numeracy groups, enabled better financial control. Many participants indicated that the most profound positive effect using the visual prototype had on their behaviour was the enhanced consideration they would give to their financial activities if they used the prototype in a real-world setting. As discussed by researchers in 2017, [51] numeracy skills have been linked to participation in a number of economic factors, as well as having the financial capability to manage day-to-day finances and savings [52]. Given this, the visual prototype provides an alternative financial interaction that addresses a number of financial difficulties facing lower numeracy groups.

7.3 Strengths and Limitations

Restraints around moderation were the main drawback to this current study. The study was designed to be conducted remotely. Although every consideration was given to the unmoderated study design, the inability to observe participants and guide them throughout the study did limit the ability to better engage with participants.

Also, the user testing tool Maze had some technical limitations. These mainly are the inability to use the animated feature within the prototype, which would have affected the participants experience using the prototypes.

Another limitation of the study was the relatively small sample size (N=40). Given the smaller sample size, fewer participants within the Low-Medium(N=13) participated in the study. Generally, the mix of ages was quite good. However, the 65+ group was not well represented within this study. As seen in Figure 22. The educational level was also disproportionately spread, as no participant indicated they had a level of education lower than secondary level, and 705 of participants indicated they have a level three or equivalent level of education.

The main strength of the study was the use of a mixed-methods design methodology. Both the quantitative and qualitative data gathered in this study provide an in-depth insight into the user's experience using the prototypes and their subjective usability and interactions. While the quantitative data had strong reliability, the qualitative data would have benefited from conducting a thematical analysis. This would have given the data a better inter-rater reliability score.

7.4 Future Research

The current study focused on producing an interactive number system that could be used in the context of mobile banking to assist low numeracy groups. Although the study results indicated that the novel approach could have a positive effect on financial management, the system itself was used in many contexts within a mobile banking app. To further refine the effectiveness and practicality of the systems, future research would need to look at its use in a more specific context, such as creating and managing a budget exclusively. Other platforms such as a tablet would also be a pivotal area to research further, as the limitations of the mobile screen size may have impacted the overall usability of the interactive visual number system.

The visual prototype research would also benefit from a broader demographic, such as the inclusion of older populations and more participants who objectively categorise as low numeracy. As there is also a 40% comorbidity between dyscalculia and dyslexia [53], a future research study involving participants diagnosed with dyslexia would provide an ever-greater insight into the overall usability of the prototype. It would also allow the opportunity to further explore any other issues with the prototype that may only become apparent with users who also have low literacy and numeracy.

7.5 Conclusion

The overall goal of this research project was to develop an alternative number system, which was not dependent on traditional symbolic based interactions, to assist low numeracy groups to conduct everyday banking tasks. In managing finances and conducting financial tasks for the subjective numeracy groups, the visual prototype reported a better usability score than the traditional prototype. Furthermore, the feedback received across both numeracy groups indicated the visual prototype interaction enabled a higher level of consideration when managing finances. The results of this study indicate that an alternative visual number system can both assist people who struggle with numeracy but also allow users to manage their finances in a more considerate way. However, the present study did

highlight, in the context of conducting everyday banking tasks, specifically for the higher numeracy groups, that slower interaction was a pain point. The causal factor of this was that the visual prototype did not match the ability of the higher numeracy group. Thus, the interaction was a source of frustration.

The effectiveness of a visually interactive banking system was researched and explored in this study. However, this novel approach raised a number of issues, which would need addressing in the next iteration. If these issues were successfully addressed, the visual number system's practicality should be further explored as an optional choice offered to every user when integrated into mobile banking. This would allow mobile banking apps to provide a means of interaction that reflects their users' ability.

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