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LONG PAPER

# An analysis of social interaction between novice older adults when learning gesture-based skills through simple digital games

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**Abstract**
This paper reports three exploratory empirical studies with older adults that had little or no prior experience with interactive technologies. The participants were introduced to interactive technology by playing games on touchscreens, playing in pairs with the assistance of a mentor. We focus on two principle aspects, the peer-to-peer interaction during these sessions, and the role of the mentor in progressing the sessions. In the case of peer-to-peer interaction we looked for ways in which players supported each other during interaction to assess the role of peer interaction in this context. In the case of mentoring, we examined the efficacy of a minimalist approach where verbal encouragement, suggestions or (in the last resort) intervention are used to provide support to learners. The sessions showed that learners typically could play and learn basic manipulations independently after initial help and guidance from mentors. We also found that peer interaction, both in verbal and non-verbal communication and cooperative action was broadly a positive influence within sessions, suggesting that there is a significant value in building confidence as well as in learning.

**Keywords** Learning · Digital skills · Older citizens · Games · Touch table · Scaffolding · Self-efficacy

## 1 Introduction

This paper reports three exploratory studies investigating an approach to help older citizens overcome reluctance to engage with digital technology. Our focus is on older people (mostly 60+) who have minimal or no skills in using digital technologies and the mentors who help them to develop their skills. In the context of the study reported here 'mentor' refers to a third-party facilitator providing support where deemed appropriate. This could be in response to requests from participants, or strategically where serious user difficulties would be imminent. The term 'minimal' covers cases in which a participant may have had a small number of lessons (1–3) sometime in the past but these lessons were neither continued, nor had the participant have had encountered some digital technology such as cash dispensers.

The digital technologies in question are touch screens where the human computer interactions are gesture-based. This eliminates the potential barrier of learning to use a mouse [1] because interactions are much more direct. There is also an increasing prevalence of touch screens in public places from check-in to health centres and hospitals, train stations and airports, and banking terminals and checkouts in supermarkets which people may need to use even though they do not have any kind of home digital device.

## 2 Motivation

The main motivation for this work was to study the dynamics of peer-to-peer interaction and the role of mentoring during introductory game-based learning of digital skills. Our previous work showed that older citizens can rapidly acquire core skills playing simple games on a touch table [2, 3].

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The premise is that relatively informal introductory learning through play can be an effective way not only of teaching core skills [4], but also of fostering positive attitudes towards digital technology and increasing learner self-efficacy. The assertion under scrutiny is that peer learning in introductory session can be effective with minimal reliance on a mentor. This encourages learning through (co) action and fosters more rapid gaining of confidence in learners.

A further objective of the work is to provide guidance to those who play the role of a mentor or buddy to an older learner. Therefore, part of our investigation is to understand how expert mentors optimally interact with learners, when and how they may intervene when learners experience issues.

Our assertion is that playing simple games offers a low-pressure, appealing way of introducing older people to digital technology. Learning takes place 'by stealth' where the participants focus is on pleasing and engaging activity rather than on the learning of interaction principles and cognitive motor skills. The use of social spaces such as community centres rather than a classroom reinforces this principle, in a relaxed atmosphere rather than a didactic environment.

The reported work is part of the ERASMUS + KA2 project 'Gameplay for Inspiring Digital Adoption'. The study is an international collaborative effort between researchers in UK, Austria, North Macedonia, and Slovenia, each having slightly different priorities in the needs and context of both learners and the availability of mentors to support the learning development. We based our objectives on previous research within the project [5], where the participants were single users, only smaller touch-based devices were used, the monitoring was performed remotely, and reporting was only on error behaviour.

## 3 Background and related work

The increased access and use of digital technology have reduced social interaction in adults because of the potential reduction in face-to-face contact that it affords [6]. However, digital technologies provide different mechanisms to enhance social inclusion and improve quality of life in older adults [7]. In the case of limited mobility, older adults use digital technology to maintain their social networks [8] and facilitate their well-being [9]. Use of technology also allows older adults to enhance their knowledge of health issues [10], reduce feelings of loneliness [11] and prevent cognitive decline [12]. Nevertheless, despite these potential affordances, older adults have the lowest computer ownership and Internet use for any age group [13].

While some older people may be well supported by younger members of their family network to help develop their skills, others may be more dependent on community-based support projects and peer to peer learning to take their first successful steps.

Although some older adults have actively embraced digital technology use, others have been more reluctant resulting in an increased digital divide [14]. In some cases, limited ICT use is associated with age-related declines in motor, sensory, and cognitive skills [15]. Nevertheless, more recent research identifies negative attitudes stemming from fear, anxiety, and lack of motivation as the main barriers to ICT adoption [16, 17]. As a matter of fact, the difference in ICT performance between older and younger users was not caused by the difference in computer knowledge, but by the tendency of older adults to underestimate their knowledge and abilities [18]. Lack of familiarity and exposure to technology is a plausible reason for this occurrence because their past employment, and education occurred before the pervasive presence of technology [19].

Having access to technology does not necessarily lead to actual technology adoption, which requires the acquirement of specific skills. Since many older adults did not use ICT in their workplace before retiring, these skills are often limited [20]. When it comes to older adults, the availability of help and support is an important factor in acceptance and use of a technology [21]. Additionally, the usability of a technology also has an impact on older adults' decision to use a technology. The growing popularity of a touch-based devices is changing perceptions of ICT usefulness and ease of usage [22]. In a recent study on tablet computer adoption, Hur, Kim and Kim [23] discovered that perceived usefulness and enjoyment are positively related to attitudes towards tablet computers, while attitudes and social influence affect the intention to use tablet computers. Finally, related to this concept, self-efficacy and expected outcomes of using a certain technology are important to older adults when deciding to engage with a specific technology [24]. Considering that their decision to use technology is intentional, where interest and motivation takes primacy over perceived skill-capacity, a person-focused approach is critical for ICT introduction and training [25]. The 'drill and practice' approach to learning has for some time been considered inappropriate in the HCI the literature [26]. Minimal instruction in support of exploratory learning is seen as a more effective approach to learning for most users. Therefore 'instruction' is minimised and introduced only in support of active learning.

Gameplay is seen as suitable for this purpose as it has certain key elements of task-orientated interaction whilst having the resonance of pleasant, appealing nonthreatening social activity. Gameplay has a strong goal-directed structure where players map intentions onto system objects and actions. In this sense it has an 'orthodox' interaction structure, reflecting established descriptions of display-led goal directed action, the cycle of display-based action, and learning through generalisation from examples [27]. Therefore, games encourage learners to engage in exploratory learning, encountering the basic principles of digital interaction.

The use of direct touch-based interaction facilitates a rapid and natural mapping between intentions and actions, even in initial exploratory action phases. Mihajlov, Law and Springett [28] suggest that older learners can rapidly acquire drag and rotate skills in early game-based interaction. We anticipated that similar rapid learning of a variety of drag/relate/tap actions would be achieved by participants.

Our work aims to use social games to address the problem of reluctance and the tendency to withdraw from technology. The environment has a key persuasive role. It is known that many older citizens hold negative attitudes towards technology [29], part of which is a perceived inability to learn and master the technology. The weakening of such attitudes is part of the mission, as is the generation of new positive attitudes and re-enactment/reinforcement of positive attitudes. Therefore, our approach facilitates a rapid sense of mastery using reality-based interaction [30] and providing scaffolding [31] to provide pathways for accelerated mastery and positive attitudes.

Attitudes may be influenced by events and interventions within interaction. Potential reinforcers of negative attitudes may, for example, be repeated failed actions, erratic and unexplainable system action, or uncomfortable reactions in the social setting. In these situations, the scaffolding approach may involve an intervention to weaken the negative consequences of such problems during exploratory interaction.

Positive self-efficacy may be engendered, for example, through appraising achievements through comparison with others [32]. This adds value to the more instrumental benefits of joint problem-solving and co-learning through action, such as learning of basic manipulations and interaction principles. Bandura [33] cites three sources of self-efficacy beliefs that relate to elements of our approach, namely enactive mastery experiences, vicarious experiences (comparisons), and verbal persuasions (or similar social influences). Enactive mastery experiences are supported with gameplay. The intrinsic appeal of games associated help to hide the learning aspect and lessen anticipation of difficulty. Playful fascination can motivate users to repeatedly try actions until mastered through practice. Also, where there is an electronic version of a familiar game it may be that positive self-efficacy regarding that game may override negativity towards technology.

Vicarious experience and verbal persuasion are designed to emanate from peer interaction and from mentor support [31]. Playing games where there is discreet turn-taking allows users to witness and be witnessed. Where the game is also competitive there is heightened motivation for peer comparison. This is coupled with the instrumental goal of reinforcing learning of skills and principles through observation of others and feedback on one's own action. Where a game involves close-coupled cooperative action, observation of action and witnessed action become interleaved. This also facilitates synchronous action where body moves coordinate both in performances of action and in conveying to partners. This type of body movement has been cited as a key dynamic of co-performance and in expert-learner dialogues [34].

Gaining vicarious experiences is only one advantage of using a design that allows peer interaction. Peer interactions can lead to 'peer learning' which 'should be mutually beneficial and involve the sharing of knowledge, ideas and experience between the participants'. Peers are basically 'other people in similar situation to each other' and 'do not have power over each other by virtue of their position or responsibility' [35].

Bandura [36] cites evaluative feedback highlighting personal capabilities as significant in raising efficacy beliefs. Positive feedback referring to ability in early stages has a particularly notable positive effect. The advantage of games, freehand drawing and a reality-based interaction platform is that rapid evidence of ability may be manifest in early performance and available for self-evaluation, peer evaluation and verbal endorsement by mentors. Reality-based interaction allows new users to recruit physical interaction skills that they possess and use in the non-digital world rather than having to learn a set of new skills [37]. The facilitation of existing skills such as drawing or expertise in a specific game also facilitates rapid exhibition of skilled performance where peer and mentor can provide positive feedback.

The need for evaluative feedback and verbal persuasion makes it necessary to think about how a mentor should act. Additionally, the mentor behaviour is important for encouraging mastery experience: Although the use of games supports enactive mastery experiences, occurring problems while playing make additional support by a mentor crucial for avoiding negative attitudes. Scaffolding as support method allows giving minimal instructions which are adapted to learner needs in exploratory learning approaches.

Wood et al. [38] used the term 'scaffolding' for describing a tutorial process where more experienced people help learners to 'achieve a goal which would be beyond his unassisted efforts'. It is crucial that learners act independently as much as possible and make their own experiences. However, the learners should reach higher goals than they would be able to achieve alone. Hence, the learners' 'success or failure at any point in time' should determine the next instructions [39]. There are clearly common characteristics in different scaffolding approaches that are appropriate for cognitive and emotional support, contingency, fading and transfer of responsibility [40]. Contingency describes that the support needs to be adapted to the needs and learning conditions of each learner. Fading means that 'the level and/or the amount of support is decreased over time'. This aspect is strongly related to the third aspect: While the support is decreased over time, the learner control should be increased which should gain to a transfer of responsibility. Hence, scaffolding as a truly dynamic process and as temporary learner-centred support method [41] can provide appropriate support in a gameplay-based exploratory learning approach.

## 4 Description of the studies

The principle objective of the studies was to assess and refine our approach to helping older adults acquire gesture-based skills using a touch screen interface. To facilitate progress, in each study the participants played digital games with the intent to reduce the sense that they were engaged in a learning process. The purpose of this approach was to have interest and enthusiasm for gameplay negate any appearance of reluctance or tendency to withdraw. The targeted gestures were tap, drag, and rotate.

The initial research protocol for all studies was established and evaluated in two small pilot trials. The results of the trials and the established protocol were shared with all project partners. Based on this protocol, the main studies were carried out separately in three partner countries, Slovenia, North Macedonia, and UK. The studies followed the same broad format, with the agreement to allow for flexibility in the research protocol to accommodate local and national differences. These differences were related to availability of participants, equipment, and overall priorities.

The established common features of all studies were the use of paired learners, an expert mentor, and an observer. Furthermore, the mentors used in the sessions had prior experience working on digital skills training with older citizens in a professional or voluntary capacity, and all had at least three years' experience. During the sessions, mentors were instructed to encourage autonomous learning in participants where possible, intervening only when it was deemed appropriate. The sessions were set up with the participants working in pairs and with support available from the researcher acting as mentor so that social interaction developed naturally. The mentor was responsible for setting up each game as well as making brief introductions relating to the goal of the game rather than the gestures required. Additionally, the mentor was available to offer support when participants appeared stuck, asked questions or system issues affected play. A pre-test questionnaire determined the name, age, and prior technology experiences of the participant.

Following the introductory brief, the participants were encouraged to begin playing the games. In study One and study Two the games were played in strict sequence, while in study Three half of the subject pairs played a different sequence from the other half. The equipment used in studies One and Three was a 32″ Lenovo Multi-surface touch screen, running MS Windows 10. Study Two used SMART Table 230i®, originally designed for children, which was customized to increase its suitability for older adults. Both devices employed multi-touch interactivity allowing for simultaneous interaction of multiple users. All experiment sessions were recorded with a digital camcorder.

### 4.1 Participants

All the recruited participants were either total newcomers to digital technology or had very little prior experience using digital devices (e.g. supermarket checkouts). Participants in the first and second study were recruited as volunteers from retirement homes in Velenje, Slovenia and Skopje, North Macedonia. The studies took place at local community facilities, near the retirement homes. Most volunteers had no or negligent experience with digital skills. In the third study, participants were recruited in collaboration with several local Age UK supported community centres and took place at those centres. Age UK is a charity organisation providing various services for older citizens. We were able to find a group of subjects who had little or no experience with digital technology. We particularly focused on those who were relatively reluctant to engage with digital technology and had not taken advantage of the free introductory courses offered by the community centres.

Altogether 88 people took part in the studies with an age range of 63 to 96 (Table 1). They were initially asked to give details of their experience level (if any) and asked about their attitude to computers. Levels of satisfaction were informally elicited at the end of sessions. The objectives of each study were explained to the participants verbally, along with the procedure. Participants were given written informed consent forms. These were also verbally explained before being signed by the participants. Video capture focussed on hands and screen, not faces, to protect participant identity. The procedure and protocol had been approved by Middlesex University Research Ethics Committee.

### 4.2 Game selection

Each study used a different combination of games, though we established a typology of games based on the interaction skill(s) to be learned, and the nature of the social interaction

**Table 1** Demographic data of participants across all studies

| | Male | Female | All | Age (mean) |
|---|---|---|---|---|
| Study One | 16 | 14 | 30 | 63–96 (76.6) |
| Study Two | 16 | 14 | 30 | 64–84 (71.1) |
| Study Three | 11 | 17 | 28 | 66–86 (75.8) |

that is facilitated. The games in each study represented a progression of core skills to be learned. The most basic gestures, tapping and dragging were embodied in the first games. Dragging would in some cases be object dragging, but in some cases freehand drawing preceded games involving object dragging. Study One and half of the sessions in study Three used freehand drawing as an opening game and introduced object dragging in the second game. Study Two introduced tapping in the first game, in which players could simply 'burst bubbles' using the tap gesture.

Games emphasising the tap, drag and rotate actions were chosen. The sequence of gesture learning was specified to allow players to master the most basic skills first. Basic tapping and dragging allows players to get used to the amount of pressure that is required for action. The more complex rotate gesture is attempted once these are introduced, as it harder to learn. The use of games for gesture learning had a distinct progression in each study from the most basic.

Study One used two packages, a freehand drawing package and a jigsaw. The freehand drawing allowed very simple tap and drag to create a shape of the player's choice. At its most simple level the tap and drag actions were all that were required to create a drawn object. More advanced features included the eraser option that was introduced where a player expressed dissatisfaction with what they had created. A colour palette that afforded changes of colour for both the drawn objects and background was made visible but without explanation. A simple Jigsaw puzzle was introduced as the second game. This game extended the drag concept with the initial manoeuvring of pieces. The placement of pieces introduces the rotate gesture. On successful completion of the game participants were shown the time taken to complete it.

Study Two used four games, Bubbles, Draw, Drag and Puzzle (for object rotation). The Bubbles game displayed several slowly moving objects of various sizes. Players were told simply to 'burst' bubbles. The Bubbles game was the only one in all three studies that initially separated the learning of a basic tap gesture from the learning of a basic drag action. This was followed by a freehand draw exercise like study one, introducing dragging.

Study Three used two conditions, with some trying initial tap and drag in freehand drawing. Others went straight to Solitaire for object dragging and Jigsaw to introduce rotating.

A further criterion for some games was the familiarity of the game concept (e.g. Solitaire is a familiar card game for many older people). The familiar game metaphor was considered a key aspect in reducing cognitive load and allowing players to easy specify their initial actions. Games in which there was negligible, or no restructuring of a familiar game would be likely to have lower cognitive load. In contrast, the nature of atomic actions would have associated cognitive load, although the familiarity game sub-tasks could support a gentle introduction to the nuances of the digital format. For example, freehand drawing most obviously maps to pen and paper drawing. However, the nature of the physical input was novel (finger rather than pen or pencil) and therefore learners would need initially to focus on the correct technique.

The games could be played by one participant whilst observed by the other, but also supported simultaneous engagement with the table in the same space on the same sub-task. One of the observations was the way in which players arranged co-play either as discreet turn taking (independent activity) and observation, or direct two-player involvement (co-operative activity).

### 4.3 Analysis

The analysis was loosely based on thematic analysis [42]. Transcripts were taken from video analysis. A set of criteria emerged from a first pass analysis from pilot studies. This included independent activity, co-learning (where players discuss and work out principles whilst playing), copying of partners (mimicry of observed actions), co-operative action (where players work out their roles in a collaborative task). This also includes observations of synchronous movement between players, where players respond to physical cues from the other in closely coupled interaction sequences.

A further category was supportive activity referring to situations in which one player offers encouragement to the other. The criteria were then analysed and refined. They were divided into peer-to-peer interaction, mentor interventions/support and errors observed. The collaboration categories are listed below:

- *Independent activity* No contact or co-ordination between players;
- *Co-operative action* Players work out their roles in a collaborative task;
- *Co-learning* Players discuss and work out principles whilst playing;
- *Peer support* Verbal encouragement from one player to another;
- *Copying of partners* Mimicry of observed actions Mentor support: Where the mentor offers practical or affective support;
- *Mentor intervention* Where the mentor takes over direct action with the device.

An incidence of independent activity was recorded where one or both players were observed performing actions separately without communicating with each other. Co-operative action was recorded where players were observed actively working together. This could include parallel actions on the same game problem where there was evidence from verbal or physical behaviour that the players were focused on a common sub-goal. This includes synchronised moves and parallel coordinated moves [43]. Synchronised moves occur when one player mimics the actions of another directly. In parallel coordinated moves players perform coordinated but different actions in support of the same sub-task. For example, one player may be dragging an object whilst the other uses their finger to pinpoint the exact location for object placement.

Examples of players negotiating and coordinating turn-taking or one player spontaneously intervening in actions initiated by the other were also recorded in this category. Our assertion is that a high degree of player cooperation supports the belief that games provide a good vehicle for exploratory introductory learning in pairs.

Co-learning activity includes initial negotiation of strategy, hypothesis generation, and co-reflection on system feedback. The generation of hypotheses refers to verbalisations of players' mental models of system operational principles or the identifications of feedback. Similarly, examples of co-reflection on system feedback refer to incidences of players sharing verbal interpretations of system behaviour and expressing reinforced, modified, or new mental models of the system.

Copying of partners includes mimicry of action where one partner either observes the other from the start of a game sub-task and then tries the same move, or when a player ceases performance of an action to observe their partner, subsequently changing their own action to the one observed.

Peer support included observed examples where one player is observed providing help in completing action, or encouragement to a co-player. The former may purely be a verbal contribution or a combination of verbalisation and explanatory gestures. The latter is examples of verbalisations that do not contain specific advice or action but provide encouragement to continue, positive feedback on action or general encouragement.

Mentor support may refer to assistance in action specification or feedback interpretation. These are examples where the mentor provides verbal hints or explanations, or a combination of verbalisation and 'air gestures' where the mentor points to on-screen items or demonstrates an action away from the actual surface (either above the device or on an adjacent surface).

Mentor support also includes examples of verbal encouragement or supportive feedback. These utterances do not contain any information or hints about action (apart from reinforcement of an achieved goal). This may occur spontaneously or in response to expressions of negativity or reluctance to continue.

A further key category is mentor Intervention, where the mentor sees fit to interject and take over direct action with the system. This could be when verbally requested by a player, when players pause and look at the mentor, or when the mentor proactively recognises a situation that requires intervention.

We created a taxonomy of user errors partly based on Don Norman's model of action [44]:

- *Unintended action* When users activate a feature by accident, in these cases, the action was not a sub-action towards a user goal, nor perceived as one;
- *Failure to complete an action* This would refer to a failure of motor control in which an action is partly performed but not successfully completed. It may also refer to cases in which there is no evidence of a motor control issue, but an action is not completed due to system rules or principles;
- *Unable to specify next action* This is indicated either by a verbalised expression, or an extended pause in action. Requests for help from mentor verbally, or simply puzzled looks in the direction of the mentor are also indicators of this problem;
- *Misinterpret feedback* This can be evidenced either by verbal or physical behaviour. Verbal expressions may suggest an incorrect interpretation of feedback. Observations of erroneous follow-one action also indicate misinterpretation of feedback;
- *Incorrect/flawed hypothesis* This is evidenced by verbalisation of an incorrect assertion about system principles;
- Execution difficulty When a player is observed struggling to initiate the physical performance of an action.

# 5 Results

## 5.1 First study

The first study reported in this paper was carried out at a retirement home in Gornji Grad, Slovenia, and participants used a large touch screen. The sessions involved pairs of learners playing together preceded by a short introduction and motivational introduction from the mentor. They all played two games, freehand-drawing, and a jigsaw puzzle.

A detailed analysis of the data shows that most of the participants needed encouragement from the mentor to begin the interaction with the device. Some participant required more time than others to respond and engage.

### 5.1.1 Acquiring the drag gesture

The participants were successful in drawing an object and thus implicitly learning the drag gesture. Subsequently, the acquirement of the drag gesture was retained in the Jigsaw game where most participants learned how to drag a puzzle piece and drop it in a corresponding screen space. They understood the goal of the interaction and connected this goal to the mental model of actual finger drawing. Additionally, most participants inferred the difference between a drag and a tap.

In most sessions, players influenced each other's performance either directly or indirectly. There were numerous examples of demonstration/explanation of an action or copying actions between partners. This was usually facilitated by a player conceding to a partner after completing an action. The watching player was observed making verbal and gestural contributions to help the player figure out moves in around half the sessions. In the other sessions the large draw space facilitated parallel action. Furthermore, there were many instances of direct cooperation where participants worked together in cooperation, switching in drawing.

During the second game, there were a few cases where participants became more independent and less patient. Examples include six cases where one player took initiative and guided the second player and six cases where participants were not interested in cooperation and worked on their own. In these situations, there was no sign of engagement with the playing partner, not even observation of the partner's actions. There were three examples of a player within a pair either giving up before the end of the session or being passive throughout the game. Only a few participants were not willing to initiate gameplay (3) or were negative towards the experiment. The identified collaboration patterns for each game are presented in Table 2 along with the frequency of occurrence.

The main erroneous actions during gameplay were a result of an accidental double-touch or physical barriers. The suggestions for corrections from the mentor were followed, however errors were still repeated. The unintended action error caused significant problems as the unintended effect of two hands on the screen had the compounding effect of causing confusing feedback, which was frequently misinterpreted by players. Motor control failures generally occurred early in the sessions as players tried to become accustomed to the required level of pressure and conventions for initial tapping and release. Less frequent occurrences included problems caused by long fingernails, and one player repeatedly failing to apply sufficient pressure to the surface. Comparatively, player performance in the second game was relatively more effective with less errors during gameplay. Table 3 shows the error types and frequency for both games.

**Table 2** Observations of collaboration patterns in the first study

| Observation | Game 1 | Game 2 |
|---|---|---|
| Independent activity | 6 | 8 |
| Co-operative activity | 15 | 41 |
| Co-learning activity | 31 | 12 |
| Peer support | 15 | 3 |
| Copy partner | 20 | 8 |
| Mentor Support | 39 | 18 |
| Mentor Intervention | 8 | 10 |

#### 5.1.2 Mentor and participant activity

Initially, the mentor tended to be very active in helping participants overcome their initial reluctance to using the device and playing the game. These examples of intervention all occurred in the first phase where neither player was able to specify the initial action. After this initial phase, the mentor was able to adopt a role in occasionally encouraging or supporting the participants with no further incidents of intervention being recorded. This encouragement was crucial and most likely only a few participants would have started gameplay in its absence. A detailed analysis shows that most of participants needed encouragement of mentor to start, some required more time than others to respond and engage. Conversely, the mentor encouragement was less needed in the second game.

In three sessions a player had declared a small amount of experience in using a computer and was paired with a beginner. In all three of these pairings the complete novice was able to follow the lead of the partner with a little experience, and did not require assistance from the mentor, and there were no recorded examples of the mentor having to provide encouragement. In three sessions participants did not cooperate on action and acted in parallel without taking cues from each other.

### 5.2 Second study

The second study was conducted at a local senior citizen community centre in Skopje, North Macedonia. Most of the participants had little experience with digital devices and their interaction experiences were mostly limited to making calls on mobile phone.

During the sessions, the participants played three games in sequence. Bubbles, where the user is expected to "pop" bubbles that continuously appear on the screen by using the 'tap' gesture. This was followed by a finger drawing game with the intention of introducing a natural approach

**Table 3** Error frequency during gameplay in the first study

| Error Type | Game 1 | Game 2 |
|---|---|---|
| Unintended action | 13 | 8 |
| Failure to complete action | 26 | 3 |
| Unable to specify next action | 3 | 3 |
| Misinterpret feedback | 2 | 1 |
| Incorrect/flawed hypothesis | 0 | 1 |
| Execution difficulty | 4 | 2 |

**Fig. 1** A couple engaged in independent play of the Bubbles game

to learning the drag gesture. The final game had users move groups of items to a predefined area by utilizing the learned drag gesture.

#### 5.2.1 Acquiring the tap gesture

The first game was the most independently played game from the set. Participants would quickly realize that bubbles can be popped by tapping and they continued this activity until they reported that they have had enough. Bubble popping was performed by either a single finger tap, a multi-finger tap, or on a couple of occasions a palm tap. In a few instances the participants would get locked into a hyper-active bubble popping behaviour. The taps would become very fast and audible and this would become so engaging to the participant that the mentor had to intervene to stop the game. In instances of unsuccessful play, a participant would either attempt to collect the bubbles with both hands, or try to move the bubbles around by performing a drag gesture. While the other participant would be popping the bubbles by tapping, this activity did not seem to be a cue for the other participant to switch their erroneous play mode (Fig. 1).

#### 5.2.2 Acquiring the drag gesture

As participants were not instructed on how to draw, and the draw game essentially began with a blank screen, in most cases drawing was initiated by one of the participants. The participant would perform the drag gesture on the screen, with the result being a coloured line, and the other participant would follow suit by copying the gesture. During the draw game participants would create separate drawings. In most sessions, they would loudly discuss what they were creating and only occasionally comment to each other about their drawings. In one specific copying instance, one of the participants started drawing by making consecutive taps and the other participant copied this movement. By the end of

**Table 4** Observations of collaboration patterns in the second study

| Observation | Game 1 | Game 2 | Game 3 |
|---|---|---|---|
| Independent activity | 22 | 13 | 12 |
| Co-operative activity | 1 | 1 | 12 |
| Co-learning activity | 0 | 0 | 6 |
| Peer support | 0 | 0 | 2 |
| Copy partner | 3 | 7 | 7 |
| Mentor support | 5 | 1 | 7 |
| Mentor intervention | 2 | 0 | 0 |

**Table 5** Error frequency during gameplay in the second study

| Error type | Game 1 | Game 2 | Game 3 |
|---|---|---|---|
| Unintended action | 8 | 0 | 0 |
| Failure to complete action | 3 | 7 | 5 |
| Unable to specify next action | 3 | 1 | 6 |
| Misinterpret feedback | 1 | 2 | 0 |
| Incorrect/flawed hypothesis | 1 | 1 | 2 |
| Execution difficulty | 2 | 8 | 5 |

**Fig. 2** An example of cooperative action of the Drag game

the segment, both participants had created dotted drawings without performing a single drag gesture. In two instances, participants tried to imitate other pictures by attempting to draw the same object as the partner had drawn. Only a few errors were recorded, principally difficulties in applying sufficient pressure to start an action (execution difficulty) or in completion of an action. The detailed results for collaboration patterns and error are presented in Table 4 and Table 5, respectively.

The following drag-based game had greater evidence of cooperative action and a few cases of supportive activities. Once a participant would figure out that items can be placed in the specified target area, he/she would encourage the other participant to also move the items currently in front of them to the target area (Fig. 2). This example of supportive activity would occur on more than one occasion. Nevertheless, in a couple of cases the self-acquirement of the drag gesture was initially difficult. While the participants would cognitively understand the simple goal of the game, they would try to achieve their goal by tapping the object first and then tapping the target area next. This activity would continue until a participant would perform an accidental drag gesture.

#### 5.2.3 Mentor and participant activity

Mentor intervention was kept to a minimum during all game play. The mentor would attempt to nudge the participants in a certain direction, but they never received specific instructions as to what is correct or incorrect gameplay. Even in cases where the participants would continue to play the game wrong, and they would not pick up on cues for'correct' action, the mentor would allow them to continue. Participants were generally encouraged to explore and interact.

All the participants were engaged (except for one participant who disengaged and allowed a partner to do everything) in playing games and even though they have demonstrated lack of digital knowledge, they have eagerly and actively learnt new touch gestures and most of them have successfully finished each game. Participants stated that they had enjoyed playing games and liked the idea of playing with others. Most participants said they would like to play again and demonstrated positive opinion for this type of technology. The whole digital initiative was described as interesting, amusing, and relaxing from the great number of participants, and none of them have faced difficulties while playing games nor felt any physical inconveniences.

It was evident that the groups comprised of participants with different levels of digital knowledge demonstrate higher level of interaction and achieve greater success in completing the tasks. Immersed in real environment, where the learner is directly in touch with the realities, participants with no prior digital experience made small incremental gesture improvements by copying and/or co-learning from more experienced and knowledgeable participant.

### 5.3 Third study

The third study sessions took place at various local community centres across the UK. The participants worked in pairs alongside each other using a large touch screen, with the mentor sitting on the opposing side. The study used a highly expert mentor with over a decade's experience of digital skills training.

Games were played in two different conditions. In the first condition, participants initially played a freehand draw game that naturally introduced the drag gesture (Fig. 3), and then followed with two additional games, Solitaire for drag and drop and Jigsaw for drag and rotate. In the second conditions, participants moved straight into the latter two games.

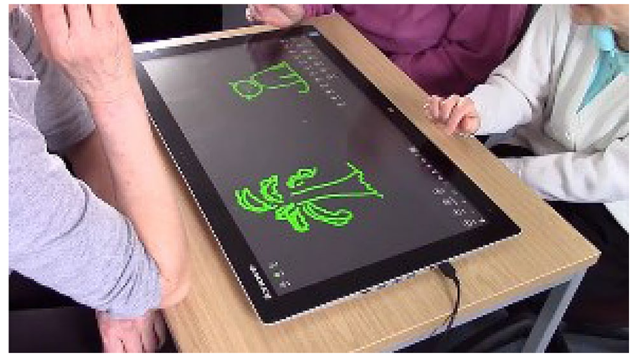

**Fig. 3** Co-players (right) and mentor and mentor (left) during a drawing task

While the cells were too small to identify significance, we were looking for indicators of a possible effect. Solitaire was a contrasting game to those used in study Two for teaching drag as it offered both discreet turn-taking and collaborative action. Participants were invited to choose how and if they played together.

#### 5.3.1 Acquiring the drag gesture

During the first game, independent action was most typical. There was only a rare occurrence where two couples, having started independently, spent some time working together on creating an image. One additional couple discovered advanced features for altering the image, which were initially hidden from view. In contrast, the drag-learning sessions in the second game showcased high collaboration activity, albeit with relatively few examples of peer support. Partners' gameplay settled on discreet turn-taking with nominal verbalised peer support. The relatively high reported incidence of co-operative activity with peer support was due to two sessions in which subjects struggled to apply the game rules for Solitaire. In these sessions the other player provided explanations and, in some cases, took over actions midway through.

Several problems were encountered in applying and maintaining the appropriate level of pressure. The reported execution difficulties were initial problems in tapping and dragging with the appropriate level of pressure. However, there was a noticeable difference in errors between participants that played the drawing game and the participants that did not. These differences related to execution difficulties and motor control failures. The scores for cognitive rather than execution or complete action issues showed a high degree of similarity. This implies that beginning a session with a simple freehand draw might improve the achieved level of competence in applying pressure and performing dragging actions. This might have the effect of reducing the potential issues faced when learners move on to a game with greater cognitive load and action complexity.

The relatively small number of observed errors in the non-draw group contrasts with the relatively high incidence of observed errors in the draw group. This was largely confined to the first minute of sessions. The typical initial verbal response where there was initial exaction difficulty often expressed nervousness and low self-efficacy. Also, some of the participants struggled with the game rules and principles. One participant required regular reminders of game principles. Also, another struggled with dragging around the 'cards' that were already laid and in doing so failed to complete the action.

#### 5.3.2 Acquiring the rotate gesture

During the third game, there was a higher level of cooperative action relative to independent activity as users were acquiring the performance of the rotate gesture. In turn, the incidence of verbalised peer support was lower as participants tended to physically intervene in each other's actions rather than communicate verbally. Collaboration between players was more direct with higher co-operative activity compared to games focused on the drag gesture. Many of the recorded phases of co-operative and independent activity were short in duration, with a player taking the lead and getting intermittent assistance from the second player. The verbal turns were most frequently co-planning of actions (Table 6).

The relatively small number of errors was in almost all cases associated with the rotate gesture, which was introduced through this game. The relatively high incidence of cooperative activity reflects a close coupling of action in the dragging and rotation to place objects. The greater incidence of unintended actions related again to the encroachment of players onto the draw space with their other hand, causing an unintended response. The consequences of the unintended actions were either the activation of a button that closed the window or causing a menu to appear over the draw space. In these cases, it was unlikely that the participants would be able to connect the system response to the action that caused it. It would therefore be likely to disrupt the flow of the experience and possibly have a negative effect on confidence and self-efficacy (Table 7).

#### 5.3.3 Mentor and participant activity

Mentor activity during the third study was focused on resolving consequences of unintended actions. Examples include encroachment of players onto the draw space with their other hand, causing an unintended response. In other instances, accidental touches would activate additional game features that would disrupt the game flow. The mentor's strategy was therefore to intervene directly and swiftly to minimise the disruption. Additionally, it was also noticeable that the non-draw group had a higher incidence of mentor support and intervention.

The smaller number of execution and failure to complete action errors made by the Draw group in subsequent play

**Table 6** Observations of collaboration patterns in the third study

| Observation | Game 1 | | Game 2 | | Game 3 | |
|---|---|---|---|---|---|---|
| | Draw | No-draw | Draw | No-draw | Draw | No-draw |
| Independent activity | 28 | / | 29 | 36 | 16 | 12 |
| Co-operative activity | 10 | / | 18 | 33 | 2 | 13 |
| Co-learning activity | 4 | / | 22 | 9 | 22 | 9 |
| Peer support | 4 | / | 13 | 29 | 13 | 29 |
| Copy partner | 11 | / | 6 | 12 | 6 | 12 |
| Mentor support | 24 | / | 30 | 33 | 30 | 33 |
| Mentor intervention | 2 | / | 15 | 25 | 15 | 25 |

**Table 7** Error frequency during gameplay in the third study

| Error type | Game 1 | | Game 2 | | Game 3 | |
|---|---|---|---|---|---|---|
| | Draw | No-draw | Draw | No-draw | Draw | No-draw |
| Unintended action | 3 | / | 3 | 13 | 3 | 13 |
| Failure to complete action | 9 | / | 18 | 22 | 18 | 22 |
| Unable to specify next action | 3 | / | 2 | 0 | 2 | 0 |
| Misinterpret feedback | 4 | / | 4 | 1 | 4 | 1 |
| Incorrect/flawed hypothesis | 3 | / | 2 | 0 | 2 | 0 |
| Execution difficulty | 11 | / | 3 | 2 | 3 | 2 |

suggests some advantage in separating the learning of basic tap and drag in its simplest form from further learning of object dragging and placement. Although they are learning motor skills, the initial cognitive load may have significance. The gentler progression may have the effect of easing the cognitive load allowing for more effective learning.

There was some evidence that the relatively high number of game rules and principles weaken the suitability of Solitaire for introductory learning. The players declared a knowledge of these rules, but two issues arose. One was simply that the rules can in the moment be forgotten causing cognitive load that disrupts the flow of action. Another is that the virtual game presents subtle contrasts with the game as played with a physical deck of cards. The 'cards have to be moved within two-dimensional space which confounded one player. Also, several players did not realise that dragging a card over already laid cards was a legal move. Four players remarked positively about the way that pieces 'snap into place' where the system recognised a correct connection between pieces.

## 6 Discussion

The high levels of interaction identified suggest that the mentored peer learning approach is effective for learning. One of the key characteristics of dyadic learning is that it potentially supports an immersive process of non-verbal action, reaction, and action co-ordination. In the context of digital skill acquisition for older citizens this represents a significant advance. The resources available for digital learning are more profoundly to do with factors such as shared action in a mutual engagement space. The key factors are a blend of cognitive resources, physical expression, and the engagement space, where knowledge is created through action, witnessed action, and connected action in a shared space.

The role of interpersonal action has been studied in the context of skilled action, and expert-learner dialogues [45], both of which are characterised by non-verbal communication, co-operative action, and shared engagement spaces. This work considers the phenomena in the contact of dyadic learning of digital skills, including learner-learner and learner mentor cooperation.

The observed collaboration types suggest that the 'expert-apprentice' dialogue, as modelled in Kendon [46], includes concepts that hold for pairs of beginners at a similar level. Co-exploration appears to have some similar dynamics to expert-novice dialogues. Novice-novice interaction includes similar dynamics. The initial proposition is grounded in verbalisations (e.g. the introduction of the task, negotiated turn-taking within a task). From that start point the dialogue may proceed through witnessed action, non-verbal dialogue (air gestures pointing), co-operative theory building and spontaneous collaborative action. Composite signals [47] are a key dynamic of dyadic interaction. They have been applied in expert interaction and expert/novice interaction. Our finding is that this can also be applied to dyadic interaction where exploratory learning is the start-point for both participants.

Learning and gaining confidence through interaction in pairs uses several combining resources. The integration of these in 'composite dialogue acts' [48] combines gesture and speech as key dynamics of information flow within dyadic interaction. Co-behaviour in the observed sessions suggests that the non-verbal dimension is a catalyst for early learning. Gesture could either mean witnessed gestures using the touch-table or 'air gestures' above the table. For co-learning the 'engagement space' appears to be both the device and the space above the table. On rare occasions the table space around the device became part of the engagement space as it was used to demonstrate an input gesture. The occasions in which partly collaborated very directly taking cues from each other's movements suggest that high levels of direct collaboration may have an advantage over discreet turn-taking as this extra dimension comes into play although one player can also withdraw and observe for periods.

Support for trial and error learning depends on learners being able to recover from errors, which includes an easy 'escape hatch' from problematic situations [49]. The most serious observed problems included accidental actions which caused unexpected pop-up menus or irrelevant windows which were platform-dependent. This happened on occasions due to an extended tap gesture, interpreted as menu selection. In these cases, it was not realistic to expect learners to successfully connect cause and effect, nor specify the next action. For example, studies One and Three, run on a Windows platform had a higher incidence of mentor intervention due to platform interference rather than study Two which was run on a dedicated platform designed for early learning. This implies a significant advantage in using single purpose devices for early learning, which is reflected in Piper, Campbell and Hollan [50], where simplicity of early use of a dedicated health application was shown to be effective for early usability and acceptance.

### 6.1 Mentor activity

The studies showed several examples in which early declarations by participants revealed low self-efficacy and negative attitudes. These initial declarations were in almost all cases not repeated once play had started and they had completed their first interactions. Several examples showed persuasive transformations [51], described as persuasion affected through types of speech act.

In the observed sessions, speech acts combined with exploratory experiences and reinforcement from playing partners combined to effect attitude change. The mentor's interactions from study Three were further analysed to establish the nature of support and interventions and circumstances in which they occurred.

The initial proactive description of necessary actions would be triggered where participants intimated that they were unable to start. This had two phases, an initialising action suggestion and (where this was insufficient) a fuller verbal and gesture-based description. The former would typically involve reference to an action metaphor and the goal state of the activity. This utilised the game metaphor to help recruit previous knowledge of the non-digital world to drive early interaction. For example, subjects were asked to 'move the card onto the stack' leaving them to work out how the 'move' action could be performed in this context. The goal state and the sub-goal structure would largely be the same as with the non-digital equivalent. Where the player was observed making a fundamental specification error, several times without displaying an ability to modify end explore, the mentor would then add a fuller explanation of game principles. There were several examples of the game metaphor being described more explicitly, to reassure users that the principles were broadly the same.

The majority of these occurred in the first two minutes of play for a specific game, and were responses to requests for help, or a prolonged observed impasse (where modification of exploratory action was absent or had ceased). A 'hint' could be to continue trying an action (where the issue was execution) or to modify an action (where the issue was in action specification or feedback interpretation). The former usually occurred early in the first game played where the action specification was sound, but the execution was problematic. The suggestion for modified action would occur where repeated attempts were showing no progress towards the correct action or action sequence. Verbal or non-verbal explanatory dialogue tended to be a simple verbalisation (e.g. try it like this) coupled with a hand gesture made over the relevant region of the table. This usually occurred post-action where there was evidence of partial learning. This could either be a correct gesture with a flawed specification (wrong feature or area) or difficulties with an execution technique. In cases where one player was experiencing difficulties, or both players experienced difficulties, the mentor would concede to the players to resolve problems themselves, only intervening if both players failed to specify an action or interpret feedback, or if the other player was unable to help a player correct an execution difficulty.

## 6.2 Mentor intervention

Almost all recorded cases in which the mentor was forced to directly intervene occurred when the players had performed an inadvertent action. Inadvertent actions included activating a menu button with their second hand, accidentally manipulating or minimising windows. Where this occurred the mentors response was to make a direct intervention to minimise the disruption to the flow of game play. The criterion for this intervention is that participants do not have the external resources (visual cues or feedback on their last action) to proceed with the game. Without the intervention the players would be at an impasse. This would prevent further learning, and, in addition, risk an adverse effect on self-efficacy. In this sense the mentor has a role in 'challenge management' ensuring that the next action facing the learner is suitable for them.

## 6.3 Affective support

The sessions have a role in introducing core skills, but also in persuading participants that they are capable of mastering digital technology. In this sense mentoring had a role in supporting attitude and behaviour change. Initial informal interviews with participants revealed several cases where low self-efficacy was expressed by participants. This was often coupled with phrases indicating reluctance to participate. Similar utterances were recorded particularly in early phases of the sessions and at the start of new games. The following three examples of mentor utterances from the transcripts map to persuasive strategies [52]. This includes persuasion to commence a game, feedback on success or completion and mitigation of unsuccessful or troubled interaction.

- *Persuasion to commence a game* In one example a player was reluctant to take the lead in playing the jigsaw game and doubted her ability. The mentor's utterance 'You're good at jigsaws you'll be good at this'–represents 'weakening the belief strength of an attitude that opposes the persuasive goal';
- *Mitigation of troubled or unsuccessful interaction* A subject's reaction on to repeated difficulty completing a Solitaire move was 'this is no good, I keep getting it wrong. The mentor's response 'you're not getting it wrong, you're just learning' was a move to 'weaken the evaluation of an attitude that opposes the persuasive goal';
- *Feedback on success* Where a player completed her first drawing and expressed a degree of satisfaction a simple verbal turn to reinforce positive self-evaluation (' that drawing looks really good') was designed to 'strengthen the evaluation of an attitude that supports the persuasive goal'.

Support is also embedded in some of the games and has a role of strengthening positive self-efficacy. Initial persuasion to engage can use a positive reinforcement strategy where a game presents a familiar activity. Learners' prior experience with the non-digital versions is a resource that can be used for initial persuasion. During sessions, a learner may express positive or negative self-assessment, in response to single incidents or the general progress of interaction. Either may be a cue for a verbal turn from the mentor. In this sense the mentor has a role in providing 'scaffolding' to effect the transformation from low-self efficacy to high self-efficacy [53].

## 7 Summary of mentoring

Findings suggest that providing emotional scaffolding is a key role for mentors. This seems primarily to be as propagating self-efficacy rather than in providing instrumental support. There were many examples where the mentor simply encouraged participants to remain positive and continue exploring. Where mentors reacted to a difficult or frustrating situation simply by demonstrating or explaining correct actions there was a less positive response and less evidence of learning. This endorses the notion that developing cognitive motor skills through practice is the key priority, allowing participants to become familiar with reactive planning and exploratory action to overcome problems. In this sense the goal is to some degree 'learning how to learn'. The learner acquires a set of strategies for dealing with situations autonomously.

Sensitivity to individual differences seems a key judgement that mentors need to make from early in sessions. This is particularly true in judging initial levels of self-efficacy and positivity towards the games. Verbal encouragement rather than physical demonstration appears to have been most effective for the more reluctant participants. The mentor role seems optimally to involve minimal intervention, to allow the learner to become adept in both the manipulations and in displayed visual scanning and action specification. The key points for intervention seem to be right at the very start if a learner does not want to take an initial touch, and where the mentor judges that the next action required by the system is beyond the current abilities of learners. The example of overlaid windows resulting from an inadvertent touch is a situation where direct mentor intervention is inevitable. A rapid intervention preserves the flow of experience for the learner and avoids diminishing the sense of mastery that may have been emerging hitherto.

## 8 Guidelines for mentors using introductory games

Based on our observations and findings from the studies, we propose the following list of guidelines for researchers conducting game-based learning sessions.

1. *Encourage learners to explore* Trial-and-error learning may not be an approach that they are used to but is the best way for them to acquire the cognitive and motor skills to move to the next level. They may be expecting a more instruction-based approach, so encourage them to learn by trying an action wherever possible.
2. *Assure learners that they cannot make catastrophic errors* Part of a learner's reluctance to explore may be fear that they may break the device or get into an unpleasantly difficult situation. Verbal assurances that there is no risk and awareness of the concept of reversibility in early interaction will assure them that their actions will not have catastrophic consequences.
3. *Allow learners time to persevere if action is slow* Multiple attempts at action, or repeatedly attempt unsuccessful action is valuable trial-and-error learning. It is best not to interrupt the learner who is engaged even if this feels frustratingly slow.
4. *Intervene when there is no realistic chance of the learner solving a problem* Challenge management is a key principle in early learning. If the game is well chosen, the challenges will be suitable for initial learning and the learner can persevere even when encountering some difficulties in completing game tasks. However, some situations do not present reasonable challenges to learners. In these situations, the integrity of the early learning experience is broken. A swift mentor intervention to restore the previous state is the best response in these situations. Inadvertent actions are likely to have consequences that the learner cannot connect to their actions or intentions.
5. *Provide demonstration-led advice if learners are having initial problems with input gestures* The earliest learning challenge is to provide correct pressure on the device to initiate a basis action. Where learners are having difficulty with this basic technique, demonstration is likely to be more effective that simply verbal encouragement. Learners may react to unsuccessful in initially taps or drags by simply pressing harder or for longer. A brief demonstration on the device or even on a table near the device will help them to grasp this technique.
6. *Emphasise enjoyment* Persuading learners to think more positively about engaging with technology is a key objective of game-based introductory learning. A sense of fun helps to relax learners and make them more inclined to persevere. If they are not enjoying a game, they should be playing a different one at a similar level of difficulty.
7. *Introduce simple games first* The most basic actions are tapping and dragging. More complex gestures such as

pinch/zoom, or rotation can be introduced when learners have gained experience of the basic actions.

8. *Reinforce positive self-reflection* Learners often express comparatively positive reactions if they perform actions well. However, this evidence of growing confidence may be fragile. It is important to reinforce this with encouraging feedback to help solidify positivity and weaken the strength of any negative self-evaluation. Reassure learners who express self-doubt.
9. *Consider social learning only where appropriate* Unless a learner has expressed a desire to work alone, introducing an additional learner in the process can be highly beneficial and should be encouraged. Peer support and co-learning can be valuable both for accelerating learning as well as confidence building. Nevertheless, it is important to monitor the relationship between participants to avoid possible negative effects. For example, ensure that the slower learner gets a substantial opportunity to learn through action if the quicker learner is dominating the device.
10. *If possible, use games that exploit existing skills and interests* The learner will have skills, interests and hobbies from their previous non-digital life experience that can help them in early learning. These may be drawing skills or fascination for a game or similar activity. Certain games may be particularly attractive to those individuals. Equally, familiar activities will help learners to recognise action cues and action procedures, making autonomous learning more rapid. Asking learners about existing interests may be helping in making selections.
11. *User smaller devices if learners have limited reach* Some learners may have back, neck and shoulder problems that prevent them from interacting comfortably with large screens. The option of a smaller screen device should therefore be available if needed.
12. *Help learners to move beyond games* Learners may declare a potential interest in learning specific digital utilities prior to an introductory session. However, many do not, particularly if they have low self-efficacy. One sign of growing confidence is that they may declare an interest in applications such as shopping, or social media. This reflects an initial perception of their usefulness, not previously coupled with the belief that they can master the necessary skills. Formal or informal elicitation can be used to specify an agenda for ongoing learning that is more application-specific, while establishing a personalised learning pathway for that individual.

## 9 Design recommendations for supporting early learning

We also propose some guidelines for design of devices used for introductory learning, based on our findings from the studies. We studied learner performance and the difficulties that learners encountered to extract generalizable recommendations for the design of systems to support early learning, whether using games or otherwise.

A key aim of the study was to facilitate trial-and-error learning as far as possible. Therefore, it would be misleading to suggest that any observed user problem was the result of a design flaw and that a change to the design would be desirable. One of the problems that our approach addresses is that older learners may not be comfortable with trial-and-error learning and that ways of making it more acceptable increase the likelihood of learner persistence. Therefore, it could be argued that an evaluation of the error data can distinguish between ‘good’ errors, and ‘bad’ errors that imply lessons about the suitability of certain design aspects. It was considered useful for learners to experience typical issues. For example, errors in the amount of pressure applied in early interaction may simply be a case of learners acquiring a basic principle of operation. However, there were a few examples that demonstrated good practice in design both artefacts and introductory learning sessions.

1. *Always provide an alternative to finger-based input* Alternative input may be more suitable for those with difficulty making direct touch input. Learners may prefer pens or pencils to interact, as they may feel more confident to accurately select objects. Additionally, some physical issues can make direct touch input more difficult (e.g. long fingernails).
2. *Avoid punishing the user for an incorrect action* Where an error such as performance of an illegal action occurs, system responses should be designed in a way that informs the learner about the nature of the problem and the expected correct action. Retain successful elements of an action if possible (e.g. if an object is dragged to an illegal location return it to the closest legal point).
3. *Avoid using games with rules that require extra explanation* As suggested earlier in this paper, use of familiar game metaphors facilitates rapid engagement and recognition of possible actions. However, games where the rules are not inherently suggested by the system image, are only suitable for learners that are already acquainted with the rules from previous non-digital experience. Without that prior knowledge, learners are burdened with extraneous cognitive load that obstructs learning.
4. *Provide mid-action indicators of successful action* Indicators of a correct action in progress are not only likely

to enhance learning, but to also help learners gain confidence. The appearance of shading for selected target areas or 'snap into place' completion for object placement allows learners to easily confirm the success of an action.

5. *Provide clear procedures for undo and task exit* Situations in which a learner cannot continue or cannot specify the next action can have a compounding effect on negative self-efficacy. The ease and speed with which such a situation can be resolved and the learner able to resume the flow of interaction is critical in sustaining learner motivation. Clear ways of being able to clear an unsatisfactory situation and resuming interaction must therefore be provided.
6. *Use simplified devices* Whenever possible, use simplified devices or dedicated learning devices to remove the risk of accidental actions producing system responses irrelevant to the current task that learners cannot comprehend or repair.
7. *Make partial analogical mappings clear* Apted, Kay and Quigley [54] emphasise the value of using real-world metaphors to help learners form helpful mental models and recognise action cues. It is inevitable that familiar game metaphors will have different aspects to their non-digital counterparts. This could be a partial restructuring of the task, or enabled actions that are not enabled in the non-digital equivalent. This can enhance learning and perceived mastery if it contributes to ease of task performance.
8. *Make recognition of selectable objects clear* It is important for learners to be able to recognise selectable parts of the interface from a visual scan. The appearance of operability in objects is often enhanced by presenting the appearance of 3D in 2-dimensional virtual objects, as they are a recognisable cue suggesting possible action.

## 10 Limitations of the studies

Conclusions from direct comparisons of learner behaviour in each study must be interpreted cautiously as the subject groups and the study designs have some key differences. Our intention was not to try to control variables between the studies given the exploratory nature of the research.

Numerical comparisons of user behaviour and errors cannot demonstrate significance in the samples that we have. There were some examples suggesting effects that we point to, but this only points to the possibility of an effect.

The studies show initial signs both of learning and positivity towards digital technology. Solidification of the detected benefits and further progress towards adoption is beyond the scope of the work reported here.

As stated above, devices running on a windows platform have several embedded peculiarities that are likely to obstruct progress in action, learning and confidence building where a mentor is not present.

Where learners have no mentor present, it is unlikely that they will be able to make progress without dedicated simplified devices. The use of Windows 10 in studies One and Three highlights the barrier that 'interfering functionality' presents in early learning. This carries the risk of learning decay in between mentored sessions. The use of more dedicated and simplified devices is a more viable approach to supporting autonomous learning.

Whilst subjects reported favourable reactions to their experience and an increased willingness to engage, we cannot assume that this persisted. There is prima facie that there is a synergistic relation relationship between perceived self-efficacy and perceived usefulness of technology application. Several subjects who had declared no interest in digital technology at the beginning revealed an interest in communications and internet shopping later in or after sessions. This would require further investigation.

Our current work encountered some age-related health issues among participants such as difficulties with finger-based input but did not explicitly address a full range of issues that typically affect the population. Choices such as the large table (for easy visual scanning and identification) were made with accessibility considerations factored in, though future work could usefully adopt a more targeted approach to mitigating perceptual cognitive and motor problems.

Ijsselsteijn et al. [55] address the use of games with explicit secondary utility, such as brain training. Our current work selected games as a vehicle for learning core skills. However, we did not allow learners to make a criteria-based choice of games to play. Presenting a suite of potential games that could be selected by learners based on appeal, usefulness for cognitive or physical training, or to learn about a specific utility would usefully build on the work reported here.

## 11 Conclusions and future work

The studies show that novice learners can rapidly explore and learn through gameplay, with minimal strategic assistance from a mentor after initial momentum is provided. The effect of co-action, and support from peer learners seems to also be a positive influence on learning. In this sense 'scaffolding' includes support from peer learners as well as a mentor.

Experiential learning theory is a holistic concept that combines experience, perception, cognition, and behaviour. Knowledge results in, and is created through, the transformation of experience. Kolb's theoretical perspective [56] on the individual experiential learning process, applied in all situations and arenas of life, was apparent in the sessions. At the beginning of sessions participants shared experiences together (concrete experience), the less digital-experienced participant observes the gesture movement of the other participant (reflective observation) and from this understanding (abstract conceptualization) acts in the correct manner (active experimentation).

Concrete experiences comprise of actually carrying out the activity (in this situation playing the games), the main focus of the reflective observation is watching on performance in the activity, considering successes and failures, while abstract conceptualization applies theory to the experience of doing the activity and finally active experimentation considers reflection to guide planning for subsequent experiences [57]. Experiential learning is a process during which adult people learn skills and develop digital knowledge through real-world experiences.

Mentoring has a strategic role that primarily involves encouraging rather than explicitly instructing users. Providing emotional scaffolding seems to be a greater priority than 'tutoring'. In cases where the players reach an impasse this may become more interventionist and more about communicating actions and procedures. Even then, the use of hints rather than explicit procedural advice seems to be most effective. Also, the swift intervention of mentors where the behaviour of the device is beyond player comprehension has a key effect on players. In both cases this can be perceived as preserving a sense of flow, as described in Csikszentmihalyi [58]. Furthermore, whilst players are engaged in the flow a game 'task' the hidden instrumental goals of learning how to explore, to plan re-actively after errors and to practice key manipulations are supported. The mentor becomes the key figure when the flow is breaking down or threatened by system behaviour.

The distribution of roles in a session changes between players and the mentor. The 'management' of this is another key role of the mentor. This includes supporting a player's attempts to weaken a negative attitude in a partner or initiating this where a partner has not initiated it. In general, we found that partners were often the source of 'interventions' that encourage the generation of positive attitudes or the weakening of negative ones.

The current study samples initiate in-situ responses to introductory gameplay sessions. It is yet unclear whether digital skills learned through gaming transfer well to other products, and what barriers there may be to this progress. Equally, it is not yet clear how positive self-efficacy generated by experiences in the sessions can best be progressed and nurtured to effect solidification. Future work will take a more longitudinal approach, monitoring progression from games to more expansive use of digital products.

Future work will include the design and evaluation of guidelines for those playing the mentor role in introductory sessions. This will include advice on design of the environment, managing the inter-partner relationship and selection of suitable games. These themes will be developed in guidance materials to be made available for those organising and conducting such sessions.

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