Text or image? Investigating the effects of instruction type on mid-air gesture making with novice older adults

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Text or Image? Investigating the Effects of Instruction Type on Mid-Air Gesture Making with Novice Older Adults

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ABSTRACT
Unlike traditional interaction methods where the same command (e.g. mouse click) is used for different purposes, mid-air gesture interaction often makes use of different gesture commands for different functions, but first novice users need to learn these commands in order to interact with the system successfully. We describe an empirical study with 25 novice older adults that investigated the effectiveness of 3 “on screen” instruction types for demonstrating how to make mid-air gesture commands. We compared three interface design choices for providing instructions: descriptive (text-based), pictorial (static), and pictorial (animated). Results showed a significant advantage of pictorial instructions (static and animated) over text-based instructions for guiding novice older adults in making mid-air gestures with regards to accuracy, completion time and user preference. Pictorial (animated) was the instruction type leading to the fastest gesture making with 100% accuracy and may be the most suitable choice to support age-friendly gesture learning.

Author Keywords
Interface design; freehand interaction; Leap motion; intuitive interaction; aging; learnability.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces—input devices and strategies, interaction styles.

INTRODUCTION
Mid-air gesture interaction has gained increasing popularity and diversification of applications in different contexts, including gaming, virtual reality, smart homes, intelligent vehicles and public interactive kiosks. Gesture-based interfaces usually use motion sensors such as the Microsoft Kinect, Microsoft HoloLens and the Leap Motion controller to allow users to make gesture commands to navigate the system and control objects on screen [1][24].

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Recent studies have been focusing on finding coherent, easy and intuitive mid-air gestures for different interaction contexts [2][6][17][19] but little research has focused on investigating the most effective way of providing to novice users instructions on how to make those gestures once they have already been incorporated in an interface. As yet, the learnability of gesture commands by novice users is still a challenging aspect of gesture-based interfaces [9], and older adults (aged 60+) face even greater challenges when interacting with this novel input method [2].

Unlike traditional interaction methods where the same command (e.g. mouse click) is used for different purposes, gesture-based interfaces often make use of different gesture commands for different functions, but first the user has to learn these commands in order to interact with the system successfully. Clear interface instructions are a fundamental feedforward mechanism for guiding novice users in using novel technologies such as mid-air gesture interaction [6]. Demonstrating “where” and “how” the system is expecting users to make gestures, and therefore allowing novice users to successfully navigate through an interface can be a challenge due to two factors. First, mid-air gestures are three-dimensional motions *per se* but, in order to provide instructions to novice users on how to make these motions, gestures are usually represented on the screen which is fundamentally a 2-d environment. Furthermore, a 3-d gesture command usually translates into a two-dimensional result: for example, users need to swipe their hands left and right in mid-air, which involves a 3-d physical motion, in order to control a 2-d slider-style menu on screen. This incongruity between 3-d commands and 2-d interfaces, combined with vague gesture names can become a usability issue for users who are not familiar with this interaction method [6].

Second, the exact spatial trajectory and kinematics of different mid-air gestures expected by the system may sometimes differ from novice users’ understanding and expectation of these gestures prior to the interaction, and, if instructions are vague, misleading, or the actual gesture is not “straightforward” then the mismatch between the user’s and the system’s expectations can lead to failed gesture attempts, frustration, and may affect the overall usability of the interface [2]. For instance, questions such as “*A finger pinch involves which fingers exactly?*”, “*How fast should I swipe?*”, “*Where should I point my finger to?*”, “*Should I rotate my index finger clockwise or anti-clockwise?*” are not uncommon and could be precisely answered by providing instructions and guidance on-screen, however, the question of what is the most effective way of doing that for a novel input method as mid-air gesture interaction is still overlooked and unknown.

Although this uncertainty about knowing how to make gestures might affect all novice users with no prior experience in gesturing in mid-air, older adults (60+) face greater difficulties and are generally more reluctant to adopt new unfamiliar interaction concepts [15][17]. Previous work [2] suggests that some gesture commands (e.g. *air tap*, *swipe*, *finger rotation*) can be unfamiliar to older adults, therefore interface instructions on how to make certain gestures should be addressed carefully to avoid failed interaction attempts. Additionally, older adults experience additional challenges as a consequence of age-related declines in range of motion and motor control, leading to imprecise and unsteady gesture-making in comparison with younger users [6][15].

Therefore, our study aims to investigate effective methods for demonstrating to novice older adults how to make different gesture commands in mid-air for the first time (i.e. providing instructions on screen) when using a Leap Motion sensor. We compared three interface design choices for presenting gesture instructions: descriptive (*text-based*), pictorial (*static*), and pictorial (*animated*).

BACKGROUND

This section first discusses the relationship between older adults and technology, and then reviews literature that focuses on theoretical and empirical research on pictorial versus text-based interfaces. Finally, work about the learnability of gestures and methods for providing gesture instructions to novice users is discussed. The body of work reviewed below was fundamental for guiding the design of our empirical study.

Older adults and unfamiliar interfaces

According to Arnott et al. (2004) [15], older adults (over the age of 60) often encounter two main obstacles to computer use: inexperience with interactive systems and unfamiliarity with novel technologies. Despite the significant growing numbers of older adults using - or interested in using - computers and technology advancements, little research had been conducted on the design of age-friendly interfaces and how to support an inclusive interaction for older users at that time. The authors designed an iconic "senior-friendly" e-mail interface and found that older users preferred literal conventional features over novel symbols and metaphors.

Gerling et al. (2012) [17] designed a motion-based game interface for older adults in nursing homes that uses full-body movements and a Microsoft Kinect sensor as a method for providing safe and engaging physical activity amongst sedentary older adults. Their findings indicate that easy gesture recall should be a fundamental aspect of an age-friendly gesture-based interface. The authors also explain that many older adults have little to no familiarity with being instructed through a computer screen, and therefore instructions should be carefully designed in order to support easy gesture learning by novice older users.

Theoretical background of pictorial interfaces

Pictorial or iconic interfaces use images to represent actions, commands or objects that can be invoked or manipulated by a user [14]. Lodding (1983) [18] writes that different pictorial types may convey meaning in different ways. For instance, *abstract* icons are meant to convey abstract concepts, whilst *representational* icons, which are more commonly used for representing gestures, are meant to represent actual physical objects and actions.

Gittins (1986) [8] suggests that pictorial and text-based instructions are different in attentional, processing and memory demands, and advocates that recognition and categorisation processes may be faster for pictures than for text and that pictorial instructions may lead to enhanced performance due to the superior advantages of visual memory over verbal memory. Alongside recognition superiority, it is implied that "representational" pictorial instructions may be a better choice for assisting novice users in learning how to use a new system by providing a set of familiar objects from which inferences about the interaction can be made [14][8].

Despite the listed advantages of pictorial instructions, Ives (1982) [3] calls attention to the difficulty of designing interface icons that communicate the intended commands without producing other connotations, whilst Witten and Greenberg (1985) [13] indicate that mismatching user's interpretations and the intended meaning of employed icons may lead to semantic errors and usability decrease. Furthermore, Lodding (1983) [18] suggests that ambiguity in iconic representations is a result of a lack of universal guidelines and principles for designing such interfaces.

Empirical studies and pictorial interfaces

There are relatively few studies that have evaluated the effectiveness of pictorial elements compared to text-based elements in interface design, however, empirical studies have been conducted for investigating abilities associated with pictorial use [10][23], for studying different interface design approaches [14][16], and for comparing forms of icons versus text commands [12]. No significant improvement in performance was found for novice users of iconic interfaces in those studies.

Egido and Patterson (1988) [4] investigated the effects of icons as a supporting aid for catalog browsing in comparison with text-based representations. In their findings, iconic representations led to slower browsing than "text" and "text plus labels". Additionally, Kacmar (1991) [5] conducted a comparison study of text labels versus pictograms in matching programming concepts where it was found that both methods combined (text labels plus pictograms) led to greater accuracy, but there was no significant difference in time. Neither study reports an advantage in completion time or accuracy obtainable through the use of pictorial representations alone.

A more recent study conducted by Griffon et al. (2014) [20] investigated the application of an iconic system interface for Visualization of Concepts in Medicine (VCM) with 20 physicians. The interface contained a filter based on icons, and icons describing medical resources. Their findings demonstrated that VCM was highly accepted by end-users and significantly increased success of information retrieval tasks in comparison with a non-VCM interface, despite requiring more time to achieve it.

In general, these studies – mainly conducted with younger and medium-to-expert users – have not found a clear and definitive advantage of pictorial elements alone in comparison with text-based information. However, the question of whether pictorial instructions would improve accuracy of mid-air gesture making for novice older adults is still an important topic yet to be explored.

Learnability of gestures for novice users

Norman and Nielsen (2010) [9] argue that a challenging aspect of gesture-based interfaces is the learnability of new gesture commands for novice users. That is, novice users need to be informed about what gestures can be used for a list of interface commands and how to make them correctly in order to proceed with a successful interaction. Interface designers and developers alongside with HCI researchers have not yet employed consistent principles and practices concerning gesture learning. Although highly relevant, this question has been largely unexplored by the HCI community so far.

Kurtenbach et al. (1994) [11] made use of auxiliary and contextual on screen animations to help novice users learn possible pen-based gesture commands within the interface, and how those gestures should be made. Similarly, Avrahami et al. (2001) [7] explored the suitability of Paper PDA, a paper-electronic interface that was designed to guide the making of single-stroke pen-based gestures.

Bau and Mackay (2008) [21] described OctoPocus, a novel concept that combined "on screen" guidance and feedback to help users learn, execute and remember mouse-based gesture commands by drawing path lines with the cursor. Despite initial positive results with medium-to-expert computer users, it is not possible to draw any conclusions on the suitability of this concept for novice users gesturing in mid-air.

METHODS

We designed a study for investigating the effects of different "on-screen" instruction types on gesture making for novice older adults with regards to accuracy, completion time and user acceptance. A list of all gestures and instructions used in the study is available as a supplementary material.

We compared three interface design choices for presenting gesture instructions (Figure 1):

- **Descriptive**: Written gesture name plus a text-based instruction on how to make the gesture.
- **Pictorial (*static*)**: Written gesture name plus a static image depicting the gesture.
- **Pictorial (*animated*)**: Written gesture name plus a 3-frame animated gif simulating a hand making the gesture.

Design and materials

The study employed a within-subjects design. Each participant was asked to make 15 different mid-air gestures to a Leap motion sensor, based on one of the three instruction types provided on screen (Figure 1): 5 gestures were shown under a descriptive (*text-based*) instruction, 5 gestures were shown under a pictorial (*static*) instruction and 5 gestures were shown under a pictorial (*animated*) instruction. Gestures differed in complexity and number of hands involved. Gesture order and type of instruction provided were counter-balanced across participants using a balanced Latin square to minimise learning and fatigue effects (Figure 2). The number of gesture attempts (correct or incorrect) and time to make each gesture correctly (including instruction reading time) were the dependent variables.

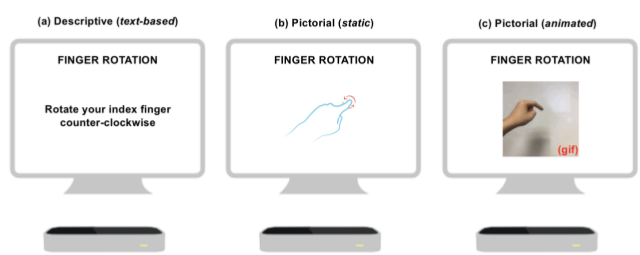


Figure 1. Examples of on screen instructions type for the "finger rotation" gesture: (a) descriptive (*text-based*), (b) pictorial (*static*), and (c) pictorial (*animated*).

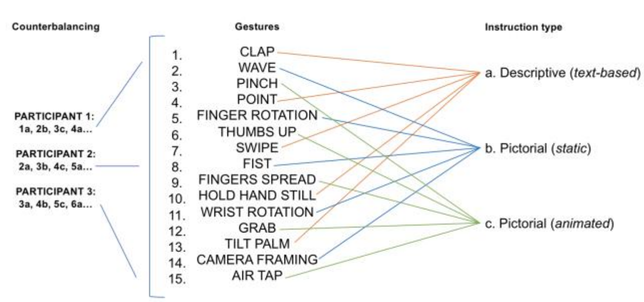


Figure 2. Study design diagram: gestures list and counterbalancing system.

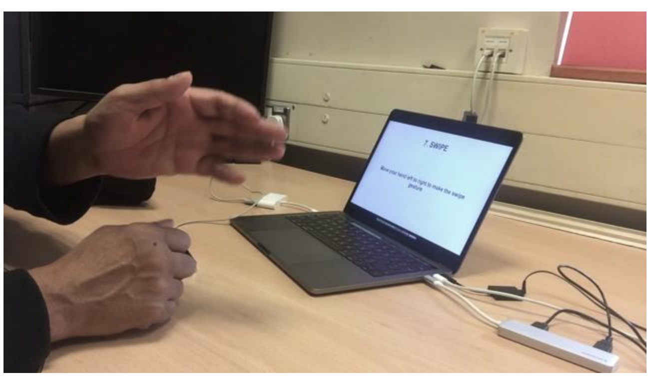
Gestures were classified as either correct (the participant made the mid-air gesture shown on screen and the Leap Motion sensor recognised it) or incorrect (the participant made a mid-air gesture, but it was not the gesture described on the screen). We collected gesture data as well as initiation and finalisation times using a Leap Motion gesture recogniser [24]. Gestures were also video recorded and reclassified by the primary researcher in case of false negatives.

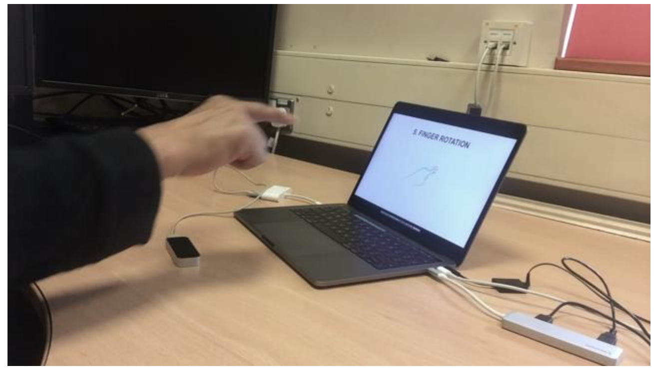
Participants

25 older adults (12 female) were recruited for the study and the mean age was 67.04 years old (SD=6.71; range 60 to 83). All participants had previous computer experience (e.g. desktop, laptop) and little familiarity with touchscreen devices (e.g. smartphones, iPad) but none of them had previous experience with mid-air gesture interaction and motion sensing devices such as the Microsoft Kinect or the Leap Motion controller. All participants were assessed on their eye-hand coordination, motor function and manual dexterity using a *Rolyan* 9-hole peg test toolkit, which is considered an appropriate tool for measuring dexterity and motor skills across the age span [25]. The study has been reviewed by the University of Reading's Research Ethics Committee and has been given a favourable ethical opinion for conduct.

Procedure

Participants were shown one of the three instruction types on screen for 15 mid-air gestures one at a time (Figure 3a to 3c). Participants were then asked to make the gesture correctly in front of the screen as fast and accurately as possible in order to proceed to the next one. In case a participant struggled in making the correct gesture, the researcher would intervene after the 10th attempt by asking the participant to proceed to the next gesture. At the end of the study, participants were asked to rate their preference and perceived easiness of each of the three instruction types.





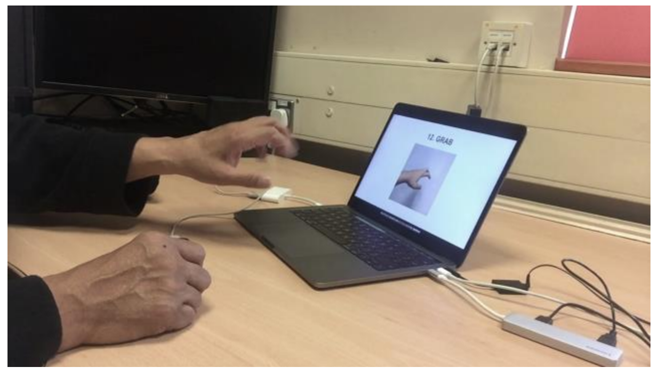


Figure 3a-3c. Participant making a "swipe" gesture based on a descriptive (*text-based*) instruction [top], a "finger rotation" gesture based on a pictorial (static) instruction [middle], and a "grab" gesture based on a pictorial (animated) instruction [bottom].

RESULTS

403 (28 incorrect and 375 correct) mid-air gestures were collected and analysed in the study. This section describes our findings in regards to accuracy, completion time and subjective ratings for each of the three "on screen" instruction types: descriptive (*text-based*) and pictorial (*static* and *animated*). All participants were able to complete the study without help.

Accuracy

Gestures made based on descriptive (*text-based*) instructions achieved 77.6% accuracy, whilst pictorial instructions (*static* and *animated*) achieved 100% accuracy across all participants (i.e. all gestures were correctly made in one attempt). A repeated-measures ANOVA was conducted on the number of gesture attempts and the effects of three instruction types. Results showed that descriptive (*text-based*) instructions led to significantly lower accuracy in gesture making in comparison with pictorial (*static* and *animated*) instructions [$F(2, 372) = 35.8$; $p < .0001$; Cohen's $d=0.87$] (Figure 4).

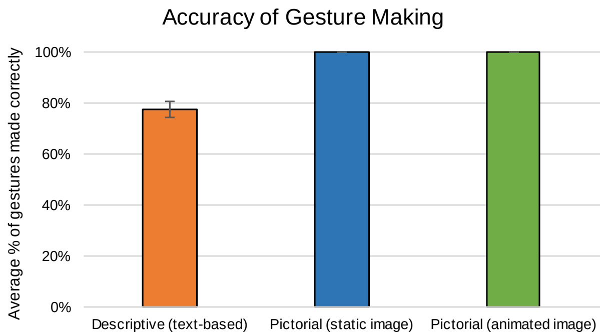


Figure 4. Average percentage of mid-air gestures made correctly at first attempt based on three instruction types. Error bars indicate standard errors.

Time to make gestures correctly

Figure 5 shows the average time (ms) taken to read/view the instruction and make each of 15 gestures correctly based on three instruction types provided on screen.

The average time taken for a descriptive instruction (*text-based*) was 2.6s, whilst for gestures shown with pictorial instructions the average time was 1.2s for the ones depicted as *static images* and 1.0s for *animated images*.

A repeated-measures ANOVA showed a significant main effect of instruction type on time necessary to make correct gestures [$F(2, 372) = 57.45$; $p < .0001$; Cohen's d=1.03]. A post-hoc Tukey HSD test confirmed significant differences between all pairs and found that the time taken to make gestures correctly with a descriptive (*text-based*) instruction was significantly higher than the time taken to make gestures with a pictorial (*static*) instruction, and the time taken to make correct gestures with a pictorial (*animated*) instruction was significantly lower than the time taken with the two former instruction types (Figure 5).

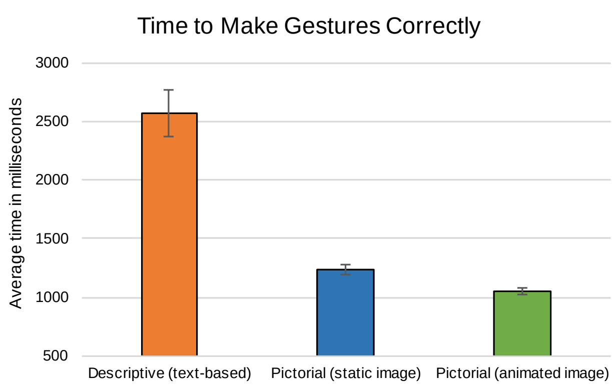


Figure 5. Average time in milliseconds taken to make gestures correctly for each of the three instruction types. Error bars indicate standard errors.

Subjective ratings

Participants rated the perceived easiness (i.e. how easy it was to come up with a gesture based on the instruction displayed on the screen) for each of the three instruction types using a 5-point Likert item ranging from (1) *Very difficult* to (5) *Very easy*. Results show that all three instruction types were rated from "*Easy*" to "*Very easy*" on average (Figure 6). A one-way ANOVA found no significant differences between the three instruction types ($p = 0.2$).

Participants were also asked to order the three instruction types based on their personal preference. Figure 7 shows the number of participants responding to "*most*" to "*least*" preferred instruction type for making mid-air gestures. Pictorial (*animated*) was the overall most preferred instruction type (15 responses), in contrast with 7 participants choosing descriptive (*text-based*) and only 3 participants choosing pictorial (*static*) as their preferred instruction type.

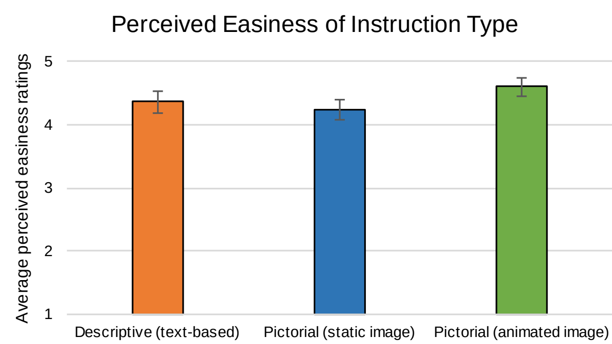


Figure 6. Average perceived easiness ratings for each of the three instruction types (1 – Very difficult; 5 – Very easy).

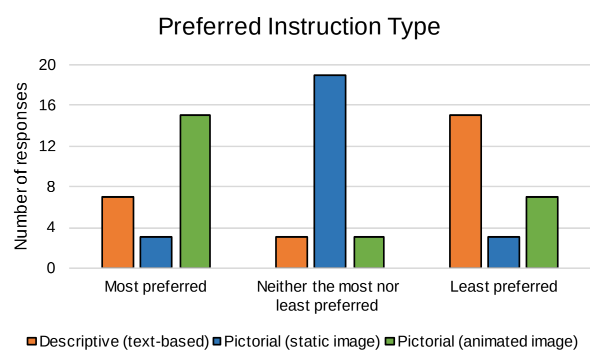


Figure 7. Number of participants responding to (1) most, (2) neither the most nor least, or (3) least preferred type of instruction for making mid-air gestures.

DISCUSSION

Our study aimed to investigate the effects of three "on screen" instruction types for guiding novice users, older adults specifically, on making correct gestures in mid-air. In previous sections, we described the importance of not only choosing suitable gesture sets for a diverse population but also the need to consider effective interface design choices for supporting the learnability of these gestures. We investigated three instruction types: descriptive (*text-based*), pictorial (*static*) and pictorial (*animated*).

Despite being positively accepted by participants, our results found clear disadvantages of descriptive (*text-based*) instructions over pictorial instructions regarding completion time and accuracy of gesturing in mid-air. Our findings showed that the latter were more effective than the former, and highly accepted by novice older adults when applied to the context of mid-air gesture interaction. Pictorial (*animated*) instructions led to faster gesture making and 100% accuracy across participants and was considered the overall most preferred instruction type by older adults in our study.

Another interesting finding was that with text-based instructions, some participants would first only read the gesture label (e.g. "swipe") to attempt making a gesture intuitively without specific guidance, and would only then read the actual gesture description if the attempted gesture was not made correctly (Figure 1). This is a possible explanation for a lower accuracy of gestures based on descriptive (*text-based*) instructions, as compared with the other two instructions type. It also suggests a higher visual hierarchy of images over text labels because the above issue was not observed in gestures shown with a pictorial instruction. Indeed, a 83-year-old participant said that she did not realise that pictorials were accompanied with written labels on the top, "*I did not see that, I was just looking at the image*", said the participant.

Two participants (aged 66 and 70) expressed that they found the animated representations of gestures to be useful but preferred text instructions because they did not want to wait for the entire animation to be complete to make a gesture. Equally, other older adults may find animations too fast due to age-related declines in cognitive processing [17][19]. Regarding the use of on-screen animations and its impact on interaction, research on age-centred web design guidelines has hinted that animated images may indeed distract older users and may place too much strain on their cognitive capabilities in web navigations [22]. Our findings, however, provide empirical evidence that animated representations of gesture commands are a suitable and well accepted method for providing on-screen instructions on gesture making for older users unfamiliar to gesture-based interactions. Furthermore, although our animated pictorials consisted of a simple 3-frame gif, it may be worth considering the impact of temporal length of animated pictorials in different interaction contexts.

In relation to the generalisability of the findings, the results of this experiment found clear support for the use of pictorial instructions over mainly text-based descriptions for gesture-based interfaces that aim to be age-friendly. Pictorial representations of mid-air gestures are visual interface elements that could better guide older users in using gesture-based interfaces, therefore minimising the chances of failed gesture attempts and increasing the overall usability of the system. Even though we aimed to focus on the often marginalised learning challenges that older users face when using novel input methods for the first time, our results may also offer an indication of how younger users unfamiliar to gesture-based interfaces could benefit from these results.

RECOMMENDATIONS FOR ON-SCREEN INSTRUCTIONS IN GESTURE-BASED INTERFACES

Despite the increasing prevalence of mid-air gesture interaction across different interaction contexts (e.g. interactive displays, intelligent cars, virtual reality and gaming), standard practices for user interface design that support novice users in learning the appropriate gesture commands is still insufficient and overlooked [1, 2, 9]. As found in the present study, both static and animated pictorials accompanied with gesture labels resulted in faster and more accurate gesture making than pure text-based instructions for novice older users. Based on our findings, a primary recommendation for the design of on-screen instructions for gesture-based interfaces would be to use either animated or static pictorials as visual guidance for supporting novice users on precise and correct gesture making. Depending on the gesture set used by a specific interface, static pictorials can be applied for representing gestures that involve a static pose (e.g. pointing, stop sign, thumbs up) and animated instructions can be applied for gestures that require more complex motions and orientation as well as direct manipulation (e.g. finger rotation, pinch and pull, swipe). For example, by depicting the required trajectory, motion, and location of a specific gesture command, animated instructions can provide spatial and temporal information of those gestures in a more elucidative way than a single static image or text descriptions are likely to achieve. An immediate implication of these recommendations is the benefit of assuring that the older population will be able to learn and interact with a gesture-based interfaces with more autonomy and less mistakes, and in a similar manner, younger users with little familiarity with gestures may also benefit from these design recommendations.

FUTURE WORK

In this work, we were mainly interested in investigating the fundamental task of effectively instructing novice users on making correct mid-air gestures by exploring the suitability of three instruction types to an older population. Choosing age-friendly interface instructions is a feedforward mechanism that can possibly lead to less frustrated and failed gesture attempts, improving the overall success of an interaction. However, this method could be possibly enhanced in future work by also exploring age-friendly feedback mechanisms for gesture making such as providing instructions on how to adjust the user's gesturing to the gesture kinematics expected by the system, once – and if – the user makes an incorrect gesture.

CONCLUSION

We have presented an empirical study that investigated the effectiveness of different "on-screen" instruction types for demonstrating to novice older adults how to make different gesture commands in mid-air for the first time. We compared three interface design choices for presenting gesture instructions: descriptive (*text-based*), pictorial (*static*), and pictorial (*animated*).

All three instruction types were highly accepted by participants, but our results showed a significant advantage of pictorial instructions (static and animated) over plain text-based instructions for guiding novice older adults in making mid-air gestures with regards to accuracy, completion time and user preference. Of the three types of instructions, pictorial (*animated*) was the instruction type that led to the fastest gesture making with 100% accuracy across participants and may be the most suitable interface design choice to support age-friendly learnability of gesture-based interactions. Although the focus of this work was to expand the understanding of how to design age-friendly gesture-based interfaces, the design implications of our findings may also benefit a greater population and may also contribute to the learnability of new gesture commands.

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